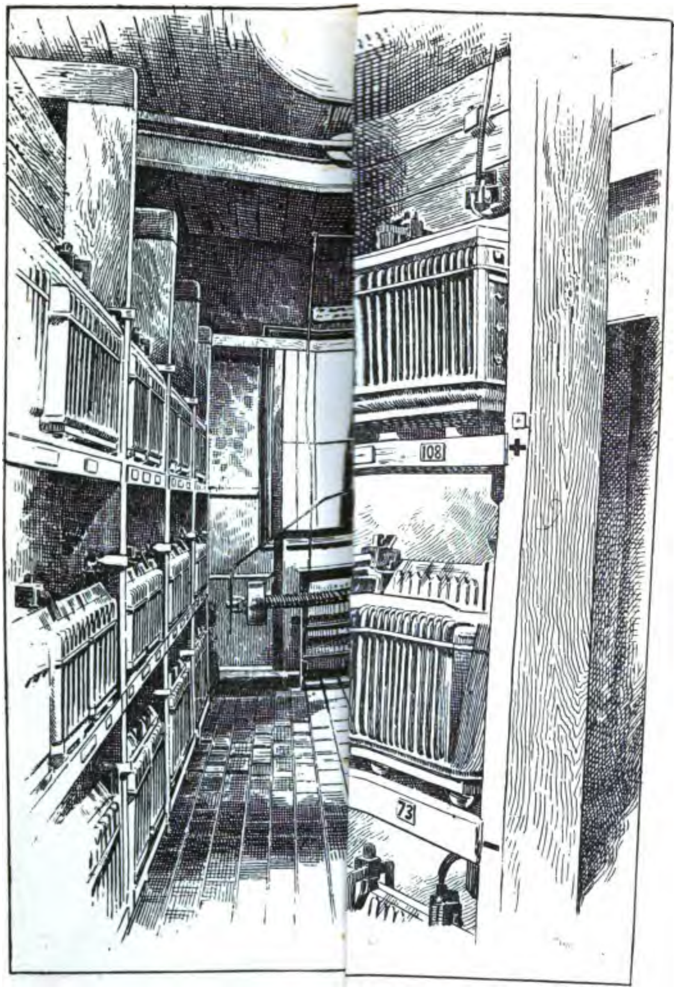
57

ELECTRIC LIGHT INSTALLATIONS

AND

THE MANAGEMENT OF ACCUMULATORS.



Frontispiece.

Electric Light Installations

AND THE

Management of Accumulators.

A Practical Handbook

BY

Lionel [illegible]

SIR DAVID SALOMONS, BART, M.A., ASSOC. INST. C.E.

MEMBER OF COUNCIL OF THE INSTITUTION OF ELECTRICAL ENGINEERS.

MEMBER OF THE AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS.

NEW EDITION, REVISED AND ENLARGED.

WITH NUMEROUS ILLUSTRATIONS.

LONDON:

WHITTAKER & CO., WHITE HART STREET, E.C.

GEORGE BELL & SONS, YORK STREET, COVENT GARDEN.

1890.

PREFACE TO THE FIFTH EDITION

CORRIGENDA.

Page 101.—Figure 17, "Page 85" occurs by accident.

Page 120.—Four lines from bottom of page, read "Figs. 23 and 24," instead of "Figs. 22, 23, and 24."

Page 230.—In 2nd, 5th and 6th lines from top of page, "Thompson" occurs; this should be "Thomson."

Page 237.—Bottom line symbol printed so $\supset\subset$ should be so $=\!\!=\!\!><\!\!=\!\!=$

Page 274.—For "Fig. 98," read "Fig. 96" on 12th line from top of page.

previous editions have now been carefully corrected.

The second part of this edition has been so much enlarged that it was thought advisable to alter the title of the volume.

PREFACE TO THE FIFTH EDITION.

THIS little book aims at filling a gap which, in practical scientific literature, is very noticeable. It presents to the reader a general survey of the practice of Electric Lighting and the management of accumulators, with such recommendations as are likely to assist him in obtaining successful results. The former editions were so rapidly disposed of that it was evident a demand for such a work existed in this country, as well as abroad, since it has been translated into the German and French languages.

A fifth edition having been called for, the opportunity has been taken of thoroughly revising, and greatly enlarging the work. The introduction of many new plates, will, it is hoped, render the text more intelligible to the reader and familiarise the eye with the manufactures of different makers; thus meeting what appears to be one of the requirements at the present moment. Two new chapters have been added. Several errors in previous editions have now been carefully corrected.

The second part of this edition has been so much enlarged that it was thought advisable to alter the title of the volume.

Up to the present time no other book has been written on the special subject of the Management of an accumulator. This has created some surprise, although, on examination, the reasons become clear enough. Two classes of persons are interested in batteries, namely, the manufacturer and the purchaser. The former, as a rule, knows comparatively little of the properties of batteries, for his knowledge is confined to laboratory tests; and it is not to his interest to publish all the shortcomings of his wares. On the other hand, the true knowledge of how a battery will act is gained only by experience extending over a long period, when the accumulator is in the hands of an unprofessional user, who rarely has the knowledge to examine the question for himself. Therefore, the privilege remains with a very few to observe, scientifically as well as practically, the working of batteries; and out of this limited class not many have the time or opportunity to write on the subject. The author has attempted to fill this gap, which lies between the manufacturer of cells and the general user, and he trusts that benefits will accrue to both.

The author feels confident that the directions here laid down, if carefully followed, will prove of great service, so that professional advice may very rarely be required. In fact, this little book is the outcome of years of labour, and of an almost unlimited number of experiments undertaken without considering the cost; for only in this manner can reliable results be obtained. The cells of the Electrical Power Storage Company, of Messrs. Elwell Parker, and similar types, are those

chiefly dealt with, because, at present, they are almost universally used, notwithstanding that many other types exist; and, though time may show some of the latter to be superior, that moment has not yet come.

To friends and correspondents the author is much indebted for so many valuable suggestions that have materially assisted him in his difficult task.

His thanks are also due to the many Firms who have kindly lent the blocks from which most of the plates in this book were printed. The presence of these illustrations will prove of great advantage to readers, so that their gratitude must be added to that of the author.

CONTENTS.

LIST OF ILLUSTRATIONS.

INDEX OF TERMS.

H_2O = Water.

H_2SO_4 = Sulphuric acid.

PbO_2 = Lead peroxide

PbO = Lead oxide.

H = Hydrogen.

O = Oxygen.

Pb = Lead.

E.M.F. = Electro-motive force, or pressure of current

Ampère = Measure for quantity of current.

Volt = Measure for pressure of current.

Watt = Volt × Ampère = Measure of force or energy.

Electrolyte = The liquid put in a cell.

s.g. = Specific gravity.

c.p. = Candle power.

ELECTRIC LIGHT INSTALLATIONS.

PART I.—ACCUMULATORS.

CHAPTER I.

DESCRIPTION OF CELLS AND THEIR MODE OF EMPLOYMENT.

THIS is intended to be a practical work, and, therefore, no attempt is made at literary style. The object of the book is simply to place before the reader a plain and straightforward statement of facts, and to treat the whole matter in as concise and clear a manner as possible. Without further introduction the reader will now be invited to consider the subject in what seems to be the natural order. Its treatment proceeds on the assumption that the reader of this little book has a general knowledge of electric lighting, and, consequently, minute details are not given here, because they can best be found in an electrical primer.

A cell, in its true sense, is the receptacle for the liquid and plates, but generally the word is employed to signify the vessel with contents complete, unless the

contrary be indicated. A number of cells, connected together, form a battery; and when this is a secondary one, it is generally termed an accumulator. The plates consist of positive and negative elements. All those of the same denomination in a cell are metallically joined together, but the dissimilar plates are not in contact one with the other, either inside or outside the cell. The plates form an electrical connection inside the cell only through the electrolyte, and outside by joining one set of plates to the other through a conductor, which may be very complex; such, for example, as a long length of wire, with one or more lamps in its course. In this condition, the circuit is said to be closed; and unless the cell be exhausted, a current flows. When the outside conductor is broken, no current passes; and the circuit is open. The only object in employing a number of plates of each kind, instead of one positive and one negative, is to obtain a low internal resistance without the inconvenience of using very large single plates. Cells are of two kinds—primary and secondary. The primary cells are made in as many ways as there are stars in the sky, but all have one characteristic; namely, that, when exhausted, the whole or part of the chemicals employed must be renewed, and sometimes the plates also. For practical electric lighting purposes such cells are of no value, notwithstanding the assertion of many makers to the contrary. One description might, however, be excepted—the chlorine cell, generally named the Upward cell, after the inventor. But even this battery has its drawbacks and cannot be employed on a large scale. It

must not, however, be supposed that a good primary battery may not one day be forthcoming, for it is quite within the bounds of possibility.

The other cells are termed secondary, because they may, without putting in fresh chemicals, be revived by simply passing a current through them. These have been very appropriately termed, by Mr. Fitzgerald, reversible cells.

In passing, it may be remarked that many cells, ordinarily termed primary, have yet the property of secondary cells. The Gaussner dry cell is a good example.

It has become a practice amongst makers of secondary batteries to call the true positives the negative plates, and *vice versa*. Therefore, not to cause confusion, the manufacturers' designations will be adhered to throughout this book.

The cells proper are made of glass or metal, and frequently of wood, lined with glass, pitch, or celluloid. For stationary work, glass is by far the best; but for movable batteries, such as are used in launches and tramcars, other materials must be chosen.

The fluids, or electrolytes, are very numerous. They may be alkaline, acid, or neutral, according to the plates employed, and other considerations.

The plates may be all metallic, or one set may be of metal and the other of carbon, or any suitable substance; and in some cases neither one nor the other is composed of metal.

To attempt a description of every existing secondary cell would be of little interest in a book written solely

for practical purposes, since there are but two sorts of cells which are of real value at the present time. In the one the plates are composed of spongy or of granular lead; and in the other, the lead plates (or some alloy of lead) are perforated, and the holes are filled with lead compounds. Of the latter type there are numerous modifications employed to obtain the same end. There is a third type, where lead plates are used in conjunction with zinc ones; but such cells cannot be reversed an indefinite number of times, owing to the fact that the zinc plates do not, at each reversal, keep to their original form, and owing also to the growth of zinc-trees. They must, therefore, be excluded, for electric lighting purposes on a large scale. These cells, however, are useful for portable lamps and laboratory work, being of comparatively light weight for the energy they contain. Thus there are two types which require to be considered and described.

Those who are anxious to study other types of cells should refer to M. Emile Reynier's treatise on Accumulators, published by Messrs. Baudry & Co., of Paris.

Cells of the plain lead type were first shown to be reversible by Planté, although earlier workers are said to have previously discovered this property. To Faure appears to belong the merit of having so modified the Planté cell as to make it a practical one; in fact, those now so largely used are but improved Faure cells.

The chief aim of all improvements in the lead plate type is to make the plates porous, yet strong, so as to offer as large a surface as possible to the electrolyte.

The second, or perforated, type may be termed pasted plates. The holes are filled with paste made by mixing red lead with sulphuric acid for the positive, thus forming lead sulphate, the negative paste being made of litharge mixed with sulphuric acid. In cells of this type as well as in those of the Planté kind, diluted sulphuric acid is employed for the electrolyte. There are many modifications of the pastes above mentioned.

The chemical action is the same for both types of plates, and may be explained generally by saying that, when the cells are charged, more oxygen exists in the positive, and more hydrogen in the negative plates than when discharged. Without giving a detailed account, a few words on the subject of their manufacture may prove of interest.

First, let us take those of the Planté type. There are still many makers of this kind of cell, each of whom has a different method of rendering the lead plates porous. Some cast them porous to start with, others build them up of lead ribbon, and most treat the plates with nitric acid before they are formed. In all cases the same end is in view, viz., porosity. The positive and negative plates are identical before they are placed in the cells. They have tail-pieces (termed by the manufacturers "lugs"), either cast on them or put on afterwards, to project above the level of the electrolyte, so that the plate itself may be completely immersed. A strip of lead is then soldered to the lugs of all the positives, and the same is done with the negatives destined for one cell. The two sets of plates are

pushed into one another so as to form a compact block, positive and negative alternately, every plate being insulated from the next one by some non-conductor, called a separator, but each set remains joined by the lead strips described above. Such a block of plates is then firmly held together by rubber bands, or by wooden frames, the wood having been boiled in paraffin wax, or by the more recent method of strips of ebonite, vulcanite, or glass. The whole is termed a "section," which is then ready for "forming." This process consists in passing an electric current, for a long period, through the cell. In practice, a large number are coupled together in series, to undergo the process. The result is that, though both positive and negative plates are identical, after a time their chemical composition is so altered that their similarity no longer exists, and they become capable of retaining a charge, which means, scientifically, that a good primary battery is made with reversible properties. The chief drawback to this type of cell is that frequent reversals are necessary in order to obtain good storage capacity, and when the maximum capacity is reached, the plates become rotten. Therefore, a long time is required before the cells can have much storage power; and reversals are troublesome as well as expensive. A reversal is accomplished by completely discharging the cells through a resistance. They are then charged the reverse way, and, to complete the process, another discharge must be given, followed by a re-charge in the original direction. Such cells are also very heavy for

their storage capacity. The only point in their favour is that a very large charging current, or rapid discharge, does not appear to injure the plates, which is the case with the pasted type. Such a battery is, therefore, very suitable for regulating the light, and for short heavy discharges, but undesirable for storage, although

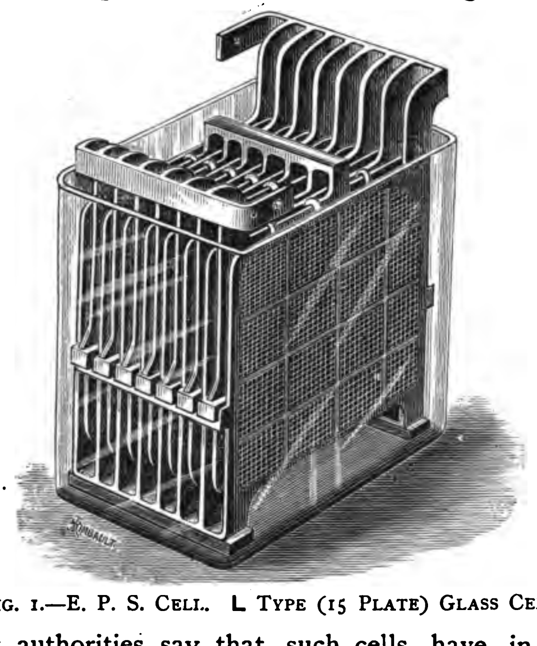


FIG. 1.—E. P. S. CELL. L TYPE (15 PLATE) GLASS CELL.

a few authorities say that such cells have, in their service, proved successful.

A few years ago, Messrs. Elwell Parker supplied many batteries of this type, but have since abandoned their manufacture in favour of the pasted

type. Plain lead plate batteries were also employed in the experimental lighting of the town of Colchester (the plates being built up with lead ribbon), which

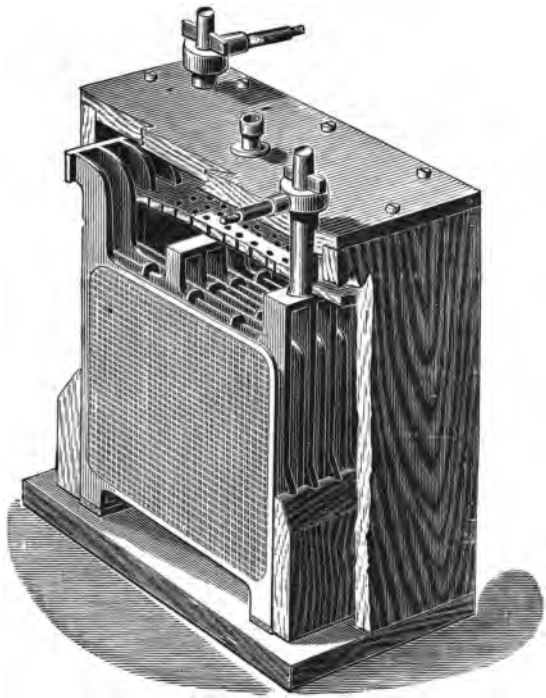
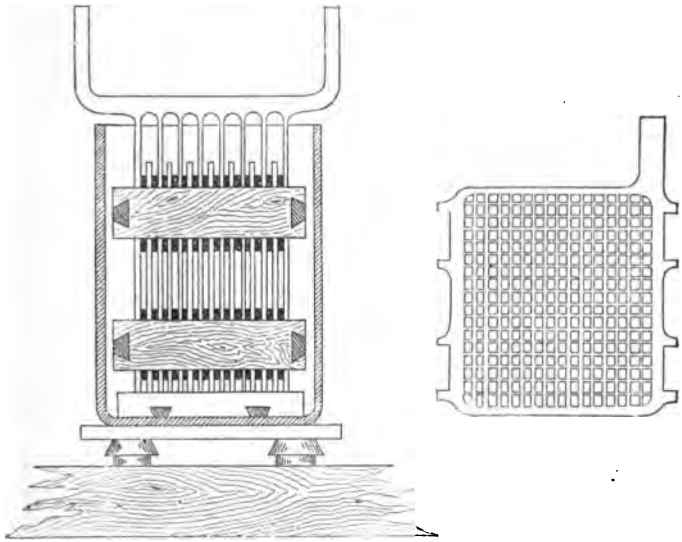


FIG. 2.—E. P. S. CELL. PORTABLE FORM. L TYPE (15 PLATE).

attempt ended in failure. The Company is no longer in existence. At the present moment, the principal users of this type of cell are Messrs. Crompton and Co., who adopt Howell's pattern. So far as the writer

is aware, these cells are not as yet in the hands of the general public.

The second type is unquestionably the most useful, notwithstanding the extra care and attention required; and these are almost universally adopted at the present



FIGS. 3 AND 4.—E. P. CELL AND PLATES. THE AUTHOR'S METHOD.

day. This book deals almost exclusively with the second type. There is little to say in respect to the first, on account of their simplicity; but, of course, all the general phenomena occurring during charging and discharging are the same in both types.

The only well-known makers, on a large scale, of

pasted plates at the present day, are the Electrical Power Storage Co. and Messrs. Elwell Parker, whose batteries are to be found in all parts of the world. It is for this reason that the cells made by the firms named are continually referred to, in speaking of these particular types. So many of the older patterns of their accumulators are in existence, that it has been thought advisable, in describing the construction of their cells, not to pass over the earlier forms.

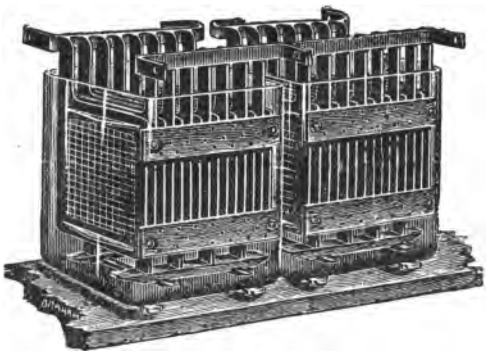


FIG. 5.—E. P. CELLS GENERAL VIEW. THE AUTHOR'S METHOD.

Pasted plates are made in many ways, but in all the object is to produce an efficient support, of lead, or grid, or other suitable material, and pastes of a hard and durable character. The E.P.S. (Electrical Power Storage Co.) cell, shown in Figs. 1 and 2, and the E.P. (Elwell Parker) plates, Figs. 3 and 5, are identical, excepting in the details described further on. They consist of lead, or an alloy

of lead, cast into plates covered with small square holes, pyramidical in form, with their bases on the surface of the plate, minute-glass shape in section, with a lug to which to attach the connecting strip of lead when built up into sections. (See Fig. 4.) Both these firms now use an alloy of lead and antimony to obtain a better plate, or grid, as it is called, the alloy being far stronger than the lead alone, and practically unacted upon by the electrolyte. Both makers formerly made the holes of the same size in the positive and negative plates; and at a later date Messrs. Elwell Parker made the holes larger in the positive. But now they have gone back to the first plan. The plates intended for positives are, as already pointed out, pasted with red lead and sulphuric acid, and those to be used for negatives with litharge and sulphuric acid. In the latter case, water would answer the purpose; but the paste thus obtained would not be so coherent.

The plates are now built up into sections by soldering the lugs of a number of positives to a strip of lead. The negatives are treated in the same way. These two sets of plates are pushed into one another, so that positive and negative alternate; and every plate is insulated from the next one. In the first form of E.P.S. make, blocks of rubber were inserted in several of the holes on each negative plate. This was improved upon by putting two or more rings of rubber round the negatives vertically, before placing between them the positives. But, in their most recent type, ebonite strips are used to insulate the plates. In the cases

where rubber is employed, a plate of thick glass is placed at each end of the section, and two stout rubber bands are made to encircle the whole, one near the top and one near the bottom of the section, horizontally. The number of negative plates always exceeds the positives by one, so that a negative is seen at each end. Of the remaining plates the edges only are visible, the plates being about a quarter of an inch apart, positive and negative alternately. There is no connection between the positives except through the leaden strip at the end of the lugs, this being left long enough to join to the next cell; and the ends of the lugs, with the strip, always remain above the liquid in the cell. These remarks also apply to the negatives. The E.P.S. section is now ready for forming.

The latest form of E.P.S. cell is called the "1888 type," as illustrated in Fig. 1; and in Fig. 6 three are shown joined in series. This form follows very closely on the improvements made by the author, as adopted by Messrs. Elwell Parker, the E.P.S. having copied the patented side-lugs for supporting the plates. The following is a detailed description of this type.

The negative plates are rigidly joined together by means of five lead bands, in addition to the usual connecting lead strip. These plates have also projections extending downwards at their lower corners. Two of the lead bands are joined to these extensions; they thus form flat supports for the section, one at each side of the block, and keep the plates raised from the bottom of the cell. Two leaden strips are attached

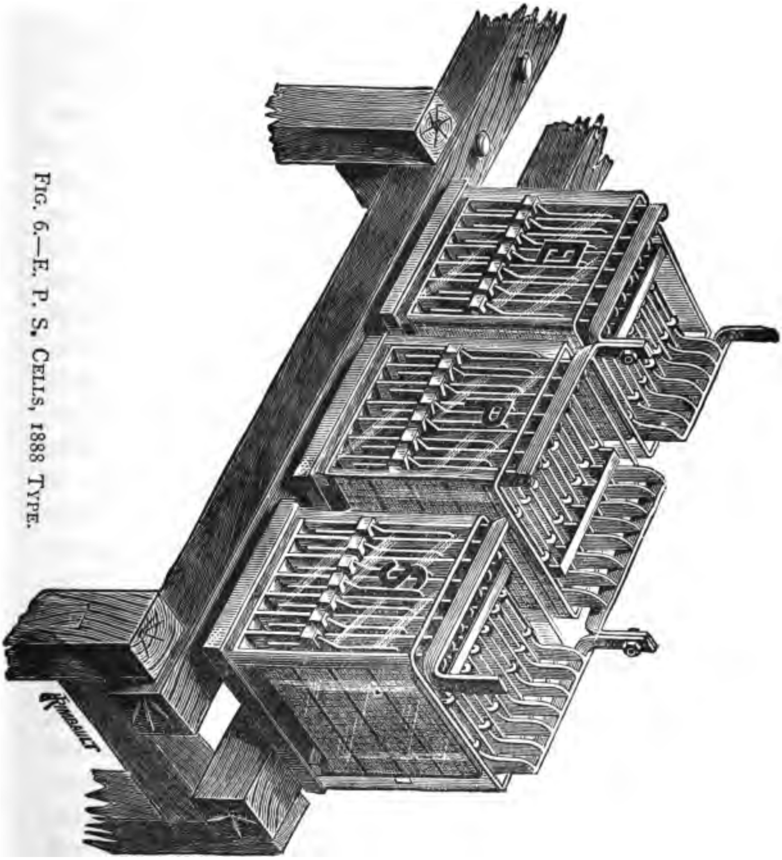


FIG. 6.—E. P. S. CELLS, 1888 TYPE.

half-way up the plates, one at each side; and these bands support the positives by means of special lugs or projections, insulation being secured by means of ebonite saddles. The upper ends of the negatives have small projecting lugs, which are connected together by the fifth leaden band. Ebonite forks are inserted between the plates to prevent the possibility of the latter shifting and touching one another. The plates are placed farther apart, in order that any plug of paste falling out of the grid may drop to the bottom of the pot, instead of sticking between the plates. It will be observed that the peculiar form given to the lower ends of the negative plates, enables the section to be considerably raised above the bottom of the cell, thus avoiding the danger of partial or complete short-circuiting, which might arise from any deposit. The section does not rest directly upon the glass, but it stands upon a small wooden frame, which has been boiled in paraffin wax. The paste also is of a harder character than that used formerly.

Although this form of section is a great step in advance, still it has several disadvantages. In consequence of the method of rigidly fixing the plates together, re-pasting would be a most difficult operation, if required to be done. As the sections are not bound up together, very great care is necessary, in order to place them in their glass cells, since the plates tend to come apart when the section is lifted. The ebonite saddles, being slight, are very easily broken. The balance of good and evil, in regard

to plates being placed farther apart, will be spoken of later on.

The author addressed a letter to Messrs. Elwell Parker early in 1887, suggesting many new methods of building up the sections, which were included in a patent taken out at the time. He specially recommended that the plates should be placed farther apart, and the holes formed on the grids of such a size that any plugs of paste falling out should drop clear to the bottom. He also suggested the prolongation of one set of plates at their lower end, in order to avoid the possibility of any deposits creating short circuits partial or complete. This improvement also permits of the old-fashioned wooden frames being dispensed with. He likewise advised making the holes smaller at the surface of the plate than within. Unfortunately, all these points were not immediately put into practice. They are now, and with the anticipated advantages. Since that time, however, the E.P.S. Co. have followed in these steps independently, and they find an increased storage in consequence, viz., as much as 10 per cent.

The variations in the E.P. type, when compared with the E.P.S., are as follows (see Figs. 3, 4, and 5). The old method was to use rubber rings to separate the plates, in the same way as in the earlier form of E.P.S. In fact, the latter makers abandoned the rubber blocks for rings long after their adoption by Messrs. Elwell Parker; and this also applies to the alloy grids, in lieu of lead ones. After the discontinuance of the rubber bands by Messrs. Elwell

Parker, the type adopted was the following. The sections were held together by strong wooden frames boiled in paraffin wax, which acted also as supports for the plates by the side lugs, slips of ebonite being placed between the plates. Pins of ebonite, fixed in the wooden frames, distanced the plates. The squares (the holes appear this shape on the surface of the plates, as seen in Figs. 4 and 5) are larger on the positives than on the negatives. The plates are also somewhat thinner.

The most recent sections are now built upon the author's patented plan, together with certain other improvements made in the plates themselves. The plates have small projecting lugs, cast upon them at their edges. These lugs fit into holes in slips of ebonite, which fulfil the treble function of forming the supports for the plates, and the frame for the sections, as well as doing duty for distance-pieces for the plates. The projecting pieces of the positive and negative plates are cast at different levels. The side lugs of the two end plates in the section are cast larger and longer, so that they project through the ebonite slips. Washers are then placed over the projections, and the latter are riveted. In this way the section is secured rigidly, and may easily be taken apart, when necessary. Ebonite slips, hair-pin shaped, and sometimes called forks, are inserted between the plates for better security, the fork being pushed over a plate in such a way that one leg is on either side.

The grids, made of alloy of lead and antimony, are passed through a special machine before pasting. This

machine is so constructed that it gives the plate slight blows with very great rapidity. In this manner the holes become burred at their edges, and, in consequence, the cavities are larger within the grid than at its surface. This improvement is due to Messrs. Drake and Gorham, and is patented by them. An equivalent process had been suggested by the author some years previously, and his method is the best, if it can be carried out successfully in practice. It is well known that, if a plate of metal containing holes truly drilled is rolled under pressure, so as to reduce its thickness, these holes become barrel-shaped, the smallest ends being at the surface of the plate. Consequently, the rolling process and the burring process apparently attain the same result. But there is one important distinction. With surface contraction, obtained by rolling, the plug of paste is wedge-shaped; whereas with the burring this is not so. And experience may show that, in the burring process, there may be a risk of the plug disintegrating in planes coinciding with the burring lines, which, from experiments made by the author, has not proved to be the case in the other process. In any event, the risk of the paste falling out is not very great, when the cells are properly used. These improvements have the great advantage of securing the paste during transport and rough usage.

The negative plates are prolonged at their lower edges at each end, so as to keep the plates well away from the bottom of the pot. The pastes employed are very hard. The holes in the positive and negative

plates are similar in size, and the distance between the plates is so regulated that, should a square of paste drop out, it would fall to the bottom. In this method of construction, of which there are numerous variations all tending to the same end, ebonite slips placed between the plates may be dispensed with, so that, if the user pleases, there is no objection to their being removed, when the plates may be observed without any obstruction to the light. But, in the E.P.S. types, these ebonite slips must not be removed on any account whatever, as they are an essential part of the construction of those cells. There are lugs, as usual, for connecting the plates; but, instead of soldering or burning on a strip of lead, the strip is cast on to the ends of the lugs; which is more convenient and looks neater. This method is now also adopted by the E.P.S. Co. The electrolyte, both in the E.P.S. and E.P. cells, consists of dilute sulphuric acid. In almost all cases, the sections rest on wooden frames or blocks, in order to avoid the risk of breaking the pots.

The following remarks apply both to the E.P.S. and to the E.P. cells. They are now connected in series, and a current is passed through them for a long period, causing the paste on the positives to become converted into lead dioxide; but the conversion is not complete, as will be explained later, and the paste on the negatives becomes partially reduced to finely divided lead. This process having been gone through, the sections are said to be formed, *i.e.*, ready for use. It will be shown in a future chapter that the whole

process of charging and discharging is a sulphating one; and where that word is employed, the meaning is that, on the positive plates, higher sulphates have been formed which cannot be reduced, except with very considerable difficulty. Therefore, this expression is used briefly for deleterious sulphating. In the same way the term "fully charged" must be taken to imply "sufficiently charged for practical purposes."

The positives may be distinguished from the negatives by their colour, which is variously termed plum, chocolate, red, and dark red. The negatives have a greyish tint on the surface, and a pale slate colour at their edges.

There is yet another kind of positive plate which deserves our attention, and which is said to be the coming plate; but on this point reserve is necessary, since it has not yet been in practical use, and there has not been an opportunity of testing it by the wear and tear of time. It is made of solid peroxide, surrounded by a band of lead or celluloid, but without a grid; and Mr. Fitzgerald may be regarded as the inventor of this plate in its present form. He gives to the material the name of lithanode, but there is not the slightest reason for giving a new name to this well-known substance. These plates are made by the Mining and General Electric Lamp Company, of the Crown Works, Lambeth. It is very probable that these lithanode plates, either in their present form, or with some modifications, will prove successful, for reasons which will be evident later on.

No matter the type of cells used, care is always necessary, though, at the same time, an intelligent man, guided by a competent teacher, will soon learn for himself what should be done on all occasions likely to arise, and, with proper attention, the troubles which so many persons encounter would never occur.

Every cell with lead plates, no matter of what form, gives 2 volts, or thereabouts. Thus one cell is useless for lighting purposes, because 50, 60, 80, and 100 volts are the most common pressures required for practical purposes. The lower pressures are generally used in small installations of, say, 30 to 50 16-candle power lamps. Beyond this number the higher pressures are employed. Consequently, an accumulator generally consists of 25 to 50 cells, or 27 to 54, so as to allow a few extra for reserve.

The cells are connected with one another by joining the leaden strip, uniting the positive plates in one cell, with the strip connecting the negatives in the next one; and so on (Figs. 5 and 6). They are then said to be connected in series. The strips may be joined by solder, by bolts and nuts, or by clamps.

Cells can also be connected in parallel, whereby two or more may be made to act as a larger one of twice or more times the capacity of the single one (if all are of equal size); but the E. M. F. will be that of one cell only. Cells of unequal size may also be coupled in like manner. Again, cells may be connected first in parallel, then in series. It is also clear that more complex arrangements are possible, such as cells in series, placed

in parallel, and then again placed in series. All combinations have their uses under special conditions.

To give a simple instance: suppose in an installation requiring 50 volts, double the capacity of single cells is required with the same pressure, and larger ones are not to be employed; then, if 27 cells were first installed, these must be increased to 54, which may be coupled in two ways. The first way is by coupling two and two thus: the positives and negatives of two cells are joined together by their connecting strips, positive to positive and negative to negative; these two are then treated as one cell, the positive at one end being joined to the negative of the next couple, and so on. The second way is to arrange the 54 cells as two complete batteries of 27 cells, in series, then to join the positive ends of these two batteries together, and also the negative ends. This is by far the better plan, because, when the accumulator consists of two batteries joined together, one battery may at any time be disconnected for cleaning or repairs without interfering with the other, so that the current is never cut off from the lines; an advantage equally existing when the accumulator consists of a greater number than two batteries in parallel. It will also be observed that, if a cell breaks and the solution runs out, thereby cutting the circuit, the current is not cut off from the lines, and no breakdown occurs. Such accidents have taken place. Two batteries in parallel keep in better order than cells coupled two and two, a lesson taught on a large scale at Lloyd's installation.

CHAPTER II.

SETTING UP THE CELLS AND THE ACCUMULATOR HOUSE.

ON their arrival, the cells should immediately be unpacked and got ready for the plates, for, unless the air is dry, they will be injured by exposure.

Strong shelves must be prepared for the reception of the cells and small boards on which to place them. Each board stands upon porcelain or glass insulators, which, in certain patterns, may be filled with oil, to insure better insulation (see Figs. 7 and 8). The glass pots, which are best for stationary work, should be placed along the shelves, and upon the boards with the insulators under the latter, leaving about an inch between cell and cell; but they must not touch on any account. The purpose of the boards is to prevent the insulators from cracking the glass cells by an unequal distribution of the weight. The shelves and cell boards should be varnished, for the sake of insulation as well as cleanliness.

Some makers recommend wooden trays, filled with sawdust, in the place of these boards; but they are best

avoided, as the sawdust soon becomes saturated with the electrolyte and gives rise to considerable annoyance without one advantage. A band, about an inch broad, of melted paraffin wax, should be applied with a brush on the outside of each cell and close to the mouth. This prevents the liquid from creeping over the top, rendering the outside wet, and thus impairing the insulation. It is of the highest importance that every cell should be per-

FIG. 7.—OIL INSULATOR. GENERAL VIEW.

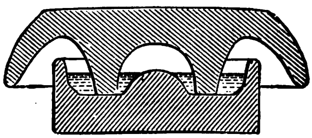


FIG. 8.—OIL INSULATOR. SECTION.

fectly insulated in order to avoid waste by leakage. The room should have nothing in it which spoils by contact with sulphuric acid fumes, and good ventilation is essential to the health of the attendant; otherwise it will be almost impossible to enter the apartment during charging hours.

The next step is to unpack the plates, and this should be done with care. They arrive in crates or boxes, one section in each. They must not be handled roughly.

The section must be taken out without disturbing a single plate, and, if packed with straw, every particle of packing must be removed. All chips or bits of paste, which may be found sticking between the plates, should be carefully taken away. In fact, the spaces between the plates must be absolutely clear, for future success in the working of the accumulator in a great measure depends on the way in which the sections have been unpacked and freed from rubbish. It is true that straw and wood are good non-conductors, but the action of sulphuric acid upon these substances carbonizes them. In this state they have considerable conducting properties, and their presence between the plates would produce leakage. At this stage it is supposed that the cells have been cleaned, the edges waxed, placed in position upon the shelves, and the plates all unpacked.

The next step is to put the sections into the pots. In a properly appointed accumulator house, this is simple enough; and the arrangements best adapted for the purpose will shortly be described. But the plan to be adopted, where luxuries do not exist, will first be considered. Remove the first glass cell from the shelf, and place it upon a piece of board laid on the ground. This board should be somewhat narrower than the cell, in order to facilitate the lifting of the latter when the plates are in. The support for the section, consisting, in most instances, of a skeleton wooden frame paraffin-waxed, is first put in the pot. When such a frame is employed, it must be carefully placed in the right way, the thicker sides of the frame carrying the plates, and, therefore, their edges resting

upon them. The thicker sides also project above the level of the frame, so that the flat side rests on the bottom. Pieces of paraffin-waxed wood must be placed under the frame, if it does not take a level bearing on the bottom. This is necessary to prevent the weight of the section breaking the glass. Now lift a section clear of the cell; lower it gently till it reaches the bottom and rests fairly upon the frame, taking care to observe that the plates have not shifted, and are quite straight and central in the cell. The section must not touch the sides of the pot, but should have a small clear space all round. Generally, the mouth of the cell is square, but if not, allow the greater space to exist between the edges of the plates and the sides of the vessel, unless the dimensions of the sections are such as not to admit of their being placed in that manner. This gives room for the acidometer, which is shown in Fig. 9. Hooks will be found most convenient for lifting the sections from the packing cases, and then placing them in the cells. In most cases two men are required for this purpose, the sections being very heavy. The hooks consist of a piece of iron wire, about No. 1 S. W. G., formed in the shape of the letter U, the free extremities being again bent into hooks, each half-circle being about two inches in diameter. The plane in which

FIG. 9.—ACIDOMETER.

the hooks are turned is such that they are not seen when the whole is viewed as a letter **U**. The rounded corners of the **U** are squared, a piece of half-inch iron gas tube having first been slipped on to avoid cutting the hands whilst lifting. When employed to lift the plates, one pair of hooks is applied to the positive lead strip, and one pair to the negative. In this way two persons can lift small or large sections with ease, and lower them gently into the cells without risk of breakage. Each cell, when completed, is put back into its place upon the shelf. To effect this in the best way, put the cell, now upon the floor, on its cell board which rests upon the insulators, and then lift the board together with the cell into position. For high shelves a staging is necessary, on account of the great weight to be raised.

The floor should be of vitrified blue brick, diamond pattern, and falling in all directions towards a drain. This admits of the floor being easily washed by flooding it with water, and the pattern allows it to be dry under foot at all times. Wooden floors rot very soon by acid spillings and by the spray.

When all the cells are in position, they are ready for connecting. The last chapter describes the methods of doing this. Solder, or bolts and nuts, or clamps, are used according to circumstances. Solder is often employed in conjunction with bolts and nuts, or clamps; but this is not essential if there is a good surface of the lead strip of one cell in contact with that of the next, and provided these surfaces have been well cleaned. The ends of the lead strips are turned up, so that those of two adjoining

cells with the junction appear thus $\perp$. If the junctions are not in thorough contact, they will become hot when a current is flowing. It is desirable to make the connections include as little lead strip in the circuit as possible, thus diminishing resistance and waste. The insulators may be steeped in paraffin wax, which has the advantage of increasing their insulating properties, besides permitting the boards, on which the cells stand, to be shifted with great ease; and in practice this is found convenient for placing them straight. The room should be cool and shady, for sunlight falling upon the cells is a constant source of breakage. Evaporation also is thus kept to a minimum. A water tap and sink should be in every accumulator house. When possible, it is a good plan to have a space behind the shelves wide enough for a man to pass. The edges of the plates can then be viewed from each side. The distance between shelf and shelf should be such that the cells may be easily looked into from above. If the battery be erected as mentioned, the edges of the plates will always face the person inspecting them. Brass or gun-metal clamps may be kept clean by brushing them over with paraffin wax, melted in a metal or glue pot, after they have been screwed up. The waxed connectors also give indications of bad contact, by the heat, generated at such points, softening the paraffin and causing it to appear of a different colour.

Clamps not made of a similar metal to that of the strips—which is almost invariably the case—frequently give trouble in consequence of the galvanic action set up between the two different metals in the presence of

moisture, resulting in the destruction either of the leaden strip or of the clamp. The author has devised a very simple means of overcoming this difficulty, viz., by placing a thin slip of zinc sheet between the lead strip and the clamp, so that there is no direct contact between the two except through the zinc; for in the case of all metals usually employed for the connecting strips, as well as the clamps, zinc is the material which is acted upon under the circumstances mentioned. Consequently, the portions likely to be injured remain intact, and only the zinc crumbles away. When necessary, it can be replaced without inconvenience and practically at no expense.

All the difficulties encountered in lifting heavy cells in confined spaces are surmounted by erecting an overhead traveller with dynamic pulley blocks, on which hangs a suitable cradle, having an adjustable counterpoise. By this plan a cell may be placed upon a shelf, or removed, in a minute, no matter how heavy it may be. Such a cradle is shown in the frontispiece. The movable counterpoise enables the platform of the cradle to remain level, whether a cell is on or off it; consequently the point of suspension need not be over the cell, which would render its service useless in the case of shelves.

The spanners employed in an accumulator house should have wooden handles, to prevent the risk of making a short circuit when they are used to tighten up the cell connections.

Those who put up batteries suffer certain incon-

veniences, such as the destruction of clothing, and sore hands. There is, however, a cure for this. The boots should be painted with paraffin wax mixed with an equal quantity of bceswax, this compound being pliable. An apron of sacking, backed with common flannel, should be worn. The clothing ought to be of woollen material, sewn with worsted, not cotton; because wool is little affected by the acid. The shirt should be dipped in a solution of strong washing soda, and then rough dried. By using these precautions the clothing is fairly well protected. A bottle of ammonia fortis ought to be kept in the accumulator house, in case of an accidental splash of acid on clothes liable to injury. The wetted stopper of the bottle applied to the stain at once neutralises the acid, and prevents a hole from being burnt in the material.

While operations are being carried on, a pail of water, rendered strongly alkaline with washing soda, should be kept close by, in which occasionally to dip the hands in order to prevent the skin from smarting under the action of the acid.

The cells are now supposed to be in position and connected up. All that remains to be done is to fill the pots with liquid, connect the dynamo cables, and start charging. It is usual to paint the positive strips of the sections red, and the negative strips black, or leave them unpainted; so that it is easy to distinguish the positives at a glance. The end cells of the battery have each a free strip, quite disconnected; one end

will be a positive, and the other a negative, if no mistake has been made in connecting up. The positive end of the accumulator is joined to the positive cable from the dynamo, and the negative to the negative. The dynamo must be of the direct current type and shunt wound, or special compound wound; but the former is by far the best. It is of vital importance that the reverse connections should not be made. Nothing, therefore, must be taken for granted: the dynamo wires should be tested. To determine the nature of the leads, proceed thus: take a vessel of any kind—a jam-pot answers the purpose—and two pieces of sheet lead about one inch wide and six inches long. Nail these lead strips to a piece of wood, one inch square in section and four inches long; so that the lead projects beyond the wood at one end. The nails on the opposite sides, which attach the slips of lead, must not touch one another in the wood; and the latter is better shellac-varnished. By means of common clamps, such as are used for laboratory primary cells, join the projecting ends of the lead plates one to each dynamo cable, putting an ordinary 16 c.p. lamp in the circuit so as to prevent too much current flowing. The dynamo cables are too large for these connections; therefore, a piece of No. 16 or 18 S.W.G. wire may be attached to the end of each cable to connect up with the testing cell. Place in the pot dilute sulphuric acid, of about one part acid to ten parts of water. Clean the mounted pieces of lead by scraping, place them in the liquid, and start the dynamo at a

moderate speed. In a few minutes examine the strips of lead; one will have become brown, and the other grey. Then trace which dynamo cable is joined to the lead that has become brown. This is the positive cable, and it should have its end painted with red shellac varnish for future distinction. The test concluded, and the dynamo stopped, the cable marked red is joined to the positive end of the battery by solder, or a suitable clamp; and the other cable is fixed to the negative end.

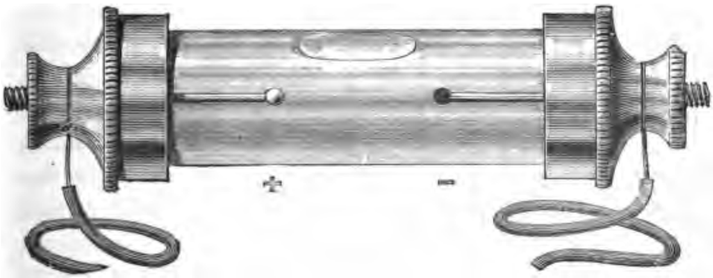


FIG. 10.—POCKET POLE TESTER.

A very pretty little pole tester, recently designed and made in Germany, is supplied in this country by Messrs. Woodhouse and Rawson. It may be put in the waistcoat pocket, and can be used without a lamp or other resistance in the circuit. (See Fig. 10, which represents this apparatus, full size.) It will be observed that there are two small knobs in the liquid, both of which are bright before using. The one connected to the positive wire remains bright, whilst the other becomes purple. After a test, the normal

conditions are restored, so that the instrument is always ready for use; and, if necessary, this may be hurried by shaking the tube. The solution appears to be an iodine compound in glycerine.

Since it is imperative to start charging directly the cells have been filled with the electrolyte, and to continue the process till the liquid sparkles sharply, or as it is generally termed, "boils," or "gases," it is better not to fill up till everything is ready. The strength of the acid solution depends upon how far the process of forming has been carried, and the better the plates are formed, the greater the advantage to the customers; otherwise a long charging has to be given before any real storage commences.

Authorities differ as to what strength the solution should be. Acid too weak, or too strong, destroys the plates. The E.P.S. cells have the sulphuric acid mixed with water till the s.g. is 1·170, and when the cells are charged, the s.g. rises to 1·200 or 1·210. The old type of E.P. cells has acid put in s.g. 1·130, and it runs up to 1·180 or 1·190; but, in the most recent type, the solution is made up to 1·150, and runs up to 1·200. It is best to purchase the acid already diluted. Pour sufficient into each cell to cover the plates completely, and to within half-an-inch of the top edge of the cell. After filling, the s.g. of the liquid falls considerably, but rises again on charging. When an accumulator is left at rest for several weeks, the positive plates are apt to get into bad condition, and not unfrequently the negatives also. This trouble can almost be entirely

remedied by doctoring the electrolyte. The following substances may be added, a small quantity to every cell:—Sulphate of potassium, sulphate of sodium, caustic soda, or common washing soda. In the case of the last-named, the active principle is the caustic soda, which is always present in the commercial samples. The author prefers using the caustic soda, which has met with better success in his hands than the other substances mentioned. The proportion which he uses is 1 oz., by weight, of solid caustic to 5 gallons of the electrolyte; but it must be added in the form of solution, say 1 oz. caustic to 5 oz. of water. This may be poured into the cells at any time, or into the electrolyte before filling the battery. When the addition is made, considerable effervescence takes place, but this is of no consequence. The effervescence is due to the neutralising of a certain amount of the acid, and the s.g. of the electrolyte being thus lowered, the E.M.F. of each cell becomes somewhat reduced. Occasionally it will be found necessary to add an extra cell to the accumulator in order to obtain normal pressure, but the necessity is rare. After a good charging, the accumulator can be left to itself for many months, without injury to the plates, which is a great convenience to the majority of users. Caustic soda should not be touched with the hand, as it burns the skin, while to clothing it is most destructive. Any weak acid serves as a neutraliser. When sulphate of potassium and sulphate of soda are the substances employed, there is no appreciable effervescence.

A good plan is to place an acidometer in every cell. By this means the specific gravity, *i.e.*, density of the liquid, in each cell, can be observed, and the variations noted during the charging, and at other times. In fact, there is no other practical and reliable method existing for ascertaining the condition of each cell. The ordinary form of an acidometer is a sealed tube, containing a paper scale, weighted at one end so that it floats upright when placed in a liquid; and its general form is that shown in Fig. 9. The weight is so adjusted that the upper part of the tube, with a portion of its scale, projects above the level of the liquid. If the liquid becomes denser, *i.e.*, of greater specific gravity, the acidometer rises, so that more of the tube and its scale is exposed above the liquid, and *vice versa.* Consequently, by noting the position, in reference to the scale, of the level of the liquid, a definite idea of the s.g. can be ascertained; and it may be mentioned that the meaning of specific gravity is a comparison between the weight of any substance with that of pure water at a particular temperature. For instance, a solid, or liquid, of s.g. 2 means twice the weight of water.

Recently, Mr. Hicks has devised a very pretty acidometer, consisting of a tube containing four flattened glass bulbs of different colours. One or more of these rise to the top of the tube, according to the specific gravity of the electrolyte, which finds its way into the tube through numerous holes (see Fig. 11). It will be observed that the top is turned hook-fashion, in order to hang over the edge of the cell and to prevent it falling to the

bottom. Thus when all four bulbs are at the top, the s.g. is 1·200; when all are at the bottom, the s.g. is 1·150; when one is down and three are up, the s.g. is 1·190, and so on. It is, therefore, only necessary to notice the colour of the lowermost bulb which is up, each colour representing a given specific gravity. These bulbs can be manufactured to rise at any desired specific gravity.

FIG. 11.—HICKS'S ACIDOMETER.

Over the top of each cell is now placed a curved glass slip, the convexity facing the liquid. These curved glasses do not cover the whole of the opening of the pot, because the lugs of the plates project above the cell. Any spray driven off is collected on the glass and runs back into the cell, thus assisting to keep the level of the liquid constant, and the room free from acid fumes.

The battery is now ready to start charging, and this should be commenced without delay.

Before proceeding to the next chapter a description of the Broomhill accumulator house will not be out of place, since it has been erected as a model. Completed now about three years, its practical convenience has been amply tested and proved, so much so that it has been copied in other installations. A representation of the room is given in the frontispiece.

The structure is about twenty-eight feet long, by eleven feet wide, and thirteen high. The roof is flat, and in the centre there is a cast glass dome, four feet in diameter. The north end of the roof has a lean-to light extending the whole width of the room, and five feet long; and it faces north. This arrangement never allows the direct sunlight to fall on the glass cells, which is frequently the cause of their breaking. In the south wall there is a large window, opening like a French casement, for ventilation; but shrubs are planted outside to keep off the sun's rays. There is ventilation also in the roof; this is obtained by the glass dome being slightly raised above the flat, so that there is an air space all round. There are two doors at the north end, facing east and west, to admit air from the outside when desired. An entrance in the north wall leads to the engine house. The shelves run north and south, and are two feet from each wall, leaving a good space between the cells and the wall sufficient for a man to pass and work. The two rows of shelves have four tiers in each (the top tier has been added since the drawing in the frontispiece was made), with a broad alley down the centre. The shelves are two and a half inches thick and nine inches broad, and rest on bearers screwed and let into standards, six on each side, two inches thick, eight inches wide, and about eight feet high. The tops are tenoned into pieces of wood, which bridge over the two-foot pathway, and are let into the wall. Bolted through each wall running north and south there is a piece of timber which these cross-pieces are let into

and screwed; thus, there is no possibility of the shelves falling inwards or outwards. The bottoms of the standards rest on a chequered blue vitrified brick floor, laid on concrete. The shelves, being broader than the standards, have the ends mortised in such a way that, though loose on their bearers, it is not possible for them to shift when once laid in their places. The distance between them is sufficient to enable the cells to stand with twelve or fourteen inches to spare, thus allowing an easy examination of the plates to be made from above. There are zinc plates nailed on to the edges of the shelves, bearing numbers in black on a white ground in order to identify each cell. The floor is slightly inclined, and, being chequered, is easily washed down without remaining wet under foot; and there is a grating at one end to carry off the water. There is also a sink and water tap in the room, and a small place adjoining (some six feet square) for an acid tank and other requirements strictly necessary for an accumulator. The walls are cemented, the ceiling match-boarded, and all woodwork sized and twice varnished. Two fifty candle-power lamps, let into the ceiling, light the room, the switches being on the shutting post of the entrance-door. There are also a large Wenham gas burner, should it ever be required; a gas soldering apparatus; and a portable lead burning arrangement devised by Mr. Stephen Holman, of Messrs. Tangye. All windows and skylights are barred, to keep out intruders of a badly-disposed kind. The design of the shelf-racks is such that, eight feet from the floor, all is clear, the lamps

even being above ceiling line. This space allows an overhead half-ton traveller to run north and south, the rails being laid upon timbers borne by the cross-pieces between shelf-standards and wall. There is a special cradle with adjustable counterpoise, so made that the cells may be lifted with perfect ease without requiring the point of suspension to be over a cell. The pulley blocks and traveller were made by Messrs. Tangye, and the cradle was devised at Broomhill. So successful is this arrangement, that in a moment, one man can move a cell, filled with liquid, from one given point to another and to any level. For the sake of rapidity, it is more convenient to have two men—one to look after the cell, and the other to move the traveller and work the blocks.

Each set of shelves holds 54 cells, containing 23 plate sections, 108 in all, one set of 54 being E.P.S., and the other 54 of E.P. make. Both accumulators are of the latest type. At every third cell there is an upright standard, and, between each cell, a loose prop is placed betwixt shelf and shelf to prevent any tendency of the wood to bend under the weight. The bottom shelf is six inches from the ground. At the south end the shelves are returned sufficiently for a cell on each row, should a few more cells ever be required for daily use, or for experimental purposes, thus leaving a passage through to the south window. All cells rest on Elwell-Parker insulators, and are connected one to another by special cast-iron and gun-metal couplers, each having an attachment to take a cable, which is most useful in case of need and for experiment. The top (fourth) shelf was added to

meet the requirements of the latest form of cells, which are larger in size, though containing the same number of plates, as shown in the drawing. Only three of these can be placed between standard and standard, instead of four; and so the extra shelf space became necessary. Against the north wall there are also shelves which carry fifteen cells, employed in connection with the counter E.M.F. governor.

The frontispiece shows all improvements, with a cell suspended in the cradle, to illustrate the method of using the latter.

In the Broomhill Accumulator House one hundred and eight cells can be unpacked, set up, and started charging in ten hours by six men; a result which probably exceeds the fastest work on record.

CHAPTER III.

CHARGING.

THE first charge differs, in some respects, from charging in the general way. There should be a steady run of thirty hours without stoppage, if possible; or not less than ten hours a day during three successive days, for the size of cells commonly in use. The electrolyte will then commence to boil; it will have a milky appearance, due to the quantity of gas bubbling through the fluid, and its s.g. will rise to about 1·200 by the acidometer. The word "boil" is meant to indicate, not a rise in temperature, but simply the appearance of a liquid in that state. The charging must be continued till every cell boils in an equal degree. The current should be kept well within the permitted maximum. For some weeks, probably, there will be a difficulty in getting the cells into an equal state; and long charging alone will secure this. Overcharging does no harm whatever, unless the current is too great. If one particular cell, here or there, will not boil, it is best disconnected from the circuit during the hours of discharge; but it must be re-established when charging

is started. Should this fail to attain the desired result the plates must be examined. Every cell should be separately tested for E.M.F., which should not be less than 2 volts; if under 1·9 volts, the cell has been discharged as low as is consistent with safety. When nearly charged, 2·1 to 2·2 volts per cell will be registered. At the conclusion of a charge, each cell for a short period of ten to fifteen minutes gives as much as 2·3 to 2·5 volts. Then the E.M.F. drops to near the normal, and, after a slight discharge, the usual E.M.F. will average 2 volts per cell, as nearly as possible. These tests are taken on open circuit, that is, when the cells are neither charging nor discharging.

There are two convenient pieces of apparatus, both made by the E.P.S. Co., for ascertaining the E.M.F. of individual cells. One instrument consists of a 2-volt lamp mounted on a small rod of ebonite, which has the end tipped with a brass point, the latter being in electrical connection with one loop of the lamp. The other loop is continued to a terminal, with a piece of wire attached, ending in a brass cap, with a point on it, which serves as a protector for the lamp when out of use. It is necessary, when testing, to place the brass point on the ebonite rod upon one strip of the plates in the cell, and the pointed cap at the end of the wire on the other strip. The plates are now short-circuited through the lamp, and, by its brightness, the condition of the cell may approximately be ascertained. The other instrument is a more scientific one, and consists of a little voltmeter, very portable and well protected (see Fig. 12),

which registers from 2 to 2·5 volts on a very open scale, graduated to tenths, and is dead-beat. Two wires leave this apparatus and are attached to a cylindrical wooden rod, having roughened brass-tubes fixed upon it at each end. One wire is connected to each piece of tube, and the tubes are insulated from one another. When used, the rod is simply laid across the cell with one hand,

FIG. 12.—E. P. S. CELL TESTER.

so that one brass tube rests upon each lead strip, the length of the rod being suitable for this purpose, while the voltmeter is held in the other hand and observed. Failing a good connection between the tubes on the rod and the lead strips, it is only necessary to move the rod file-fashion, when the roughness on the tubes will clean the lead, and establish good contact. Messrs. Nalder,

the Walsall Co., and other firms have now followed suit in making neat little voltmeters for this purpose. Figure 13 is an illustration of the Walsall Co.'s voltmeter, graduated by tenths up to 4 volts. There are no permanent magnets in it, and the current acts against the force of gravity.

Since the sizes of the E.P.S. and E.P. plates are the

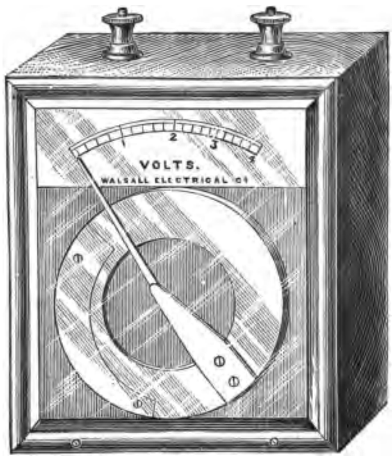


FIG. 13.—WALSALL CO.'S VOLTMETER.

same, and all conditions under which they act are similar (and probably these remarks will also apply to the Lithanode plates), the charging rates may be regarded as common to all plates of the pasted type, which have equal areas. Several sizes of plates are made; but, for electric lighting work in permanent installations, those termed L plates by the E.P.S. Company are almost

exclusively used. Those of the E.P. make are similar in size. Cells are made with 15, 23, or 31 plates in each, sections of this size being found the most convenient in practice. Cells containing 31 are not much employed, on account of their great weight. It is not, perhaps, going too far to say that, at the present time, the 15 and 23-plate cells, of the E.P.S. or E.P. make, are in almost universal use for stationary work.

The proper charging rate is 5·3 ampères per square foot of positive plate. Thus in a 15-plate cell, which contains 7 positives, 20 to 22 ampères should not be exceeded for charging; in the 23-plate size with 11 positives, 33 ampères is the maximum charging current. For the L size of plate the rate may be expressed by saying that 3 ampères per positive plate is the charging current. If a much larger current is passed, the cells boil as if they were fully charged, showing that the surface of the plates is insufficient for the current to act upon; and the excess of current does its work by simply decomposing the water of the electrolyte, creating volumes of gas, and heating the liquid. Independently of this waste, the plates are injured. In the most recent types, the grids and paste have been so much improved that it is possible to charge, without injury, a 15 and a 23-plate cell as high as 30 and 46 ampères respectively. Still, it will be on the safe side if the charging rates are not made larger than the figures given above.

If the E.M.F. of the charging current is 10 per cent. above that of the accumulator, it will be found that

about the proper amount will flow. The exceptions are at the commencement of charging, and a short time before the cells boil. The E.M.F. of the charging current must be lower at the start, and greater at the end of the run, in order to keep the current constant; for the E.M.F. of the cells, that is the counter pressure to the current flowing from the dynamo, is low in the first case and high in the latter. Where no provision exists for keeping the charging current constant, it will be found that if, at starting, it is normal, then, as charging proceeds, the current grows less and less; consequently the time required to run, in such cases, is very much longer than when the current can be kept constant. If the charging current is very small, say one-tenth of the maximum, then, however long the run, the cells do not appear to charge, unless they be in perfect order, and the insulation exceedingly good; which is rare. So much for the practical side of the charging question.

The result of charging is to convert the $PbSO_4$ on the positive plates to PbO_2, which change is thus effected: SO goes to the electrolyte in exchange for O, the liberated H_2 of the water (H_2O) joining with the SO_2 form H_2SO_4. The next action is another atom of O joining the PbO, making PbO_2, and the liberated H_2 of the H_2O going to the PbO of the negative plate, forms $Pb+H_2O$. These chemical actions may be thus represented :—

	Positive.	Electrolyte.	Negative.
1st stage	$PbSO_4$	$H_2SO_4 + H_2O$	PbO
2nd ,,	PbO	$H_2SO_4 + H_2O$	PbO
3rd ,,	PbO_4	$H_2SO_4 + H_2O$	Pb

The first stage indicates the discharged cell.

In the second stage, a molecule of water has been removed from the electrolyte, and one of H_2SO_4 added, thus increasing the strength of the acid solution. This remains unaltered in stage 3. Hence we see why the s.g. of the electrolyte increases as the charging advances. It will also be noticed that the H_2SO_4, originally put in, appears to play no part whatever, beyond making the water a good conductor; yet if no H_2SO_4 has been added in the first instance, the chemical actions are not quite the same, and the plates are soon injured by secondary actions, giving at the same time a lower E.M.F.

The chemical actions are probably far more complex than those given above, but generally and diagramatically the explanation is fairly correct.

There is, however, an additional action which proceeds during charging, for gas is given off at all periods of the charge, first from the positives only, and later from the negatives. This tends to prove that water is being decomposed, the O of which does not unite with the paste of the positives; and that H is absorbed in the negatives, or goes into chemical combination with them. Finally, when the end of the charging approaches, and the negatives can absorb no more gas, H is given off from these plates. This action is evidently a waste of energy.

There is far greater loss with storage than is generally supposed, notwithstanding that many eminent men have shown great efficiency in laboratory tests. For practical purposes such tests are worthless, and no one is recommended to expect more than 65 to 70 per cent. of efficiency in the long run. These are approximately the figures, obtained from six accumulators over extended periods.

In getting current through the battery in the first instance, there must be a loss of about 15 per cent., viz., the average difference between the E.M.F. of the charging current and the E.M.F. of the accumulator. Then power is required to get it out, if such an expression may be allowed. There is loss from leakage from local action, from cells being in bad order at times, and from many other causes, which do not exist in the usual laboratory tests.

If the strength of the acid solution is above 1·700, bad sulphating rapidly ensues, with great loss of capacity, although giving a good E.M.F.

The level of the liquid in the cells must be kept constant. To effect this, the first few additions of fluid should be H_2SO_4 s.g. 1·150 or 1·170; after this only water, unless it is found, on completion of the charge, that the acid is below the normal strength, in which case fill a few times, when necessary, with acid solution, as already mentioned.

Two phenomena which have frequently puzzled the users of cells are worthy of mention. One is that, when a new battery is erected, on its receiving a

considerable charge, the s.g. of the electrolyte is found to have risen, as is usually the case. This increase of the s.g., after standing a few days, or even hours, is partly or wholly lost; a state of things which may continue for many chargings. When this does occur, it is a proof that the plates have not been very fully formed, and chemical action goes on within the plates while the battery is standing. The second phenomenon is that, at all times, when charging is first started, there is a slight fall in the density of the liquid, which is soon recovered. This is also due to some peculiar chemical action set up at the commencement of the charge. It is assumed in the first case that no discharge has been taken, and in both that the plates are in good order. No disadvantages attach to these phenomena.

It is found that, when the cells are fully charged, only a very small proportion of the $PbSO_4$ has been converted into PbO_2. Whether this is due to the blocking up of the material, from some cause or other, it is difficult to say. Mr. Swinburne, in "The Electrician" of July 10th, 1885, writes: "Some years ago, when I made a large number of experiments on batteries, I found in no case more than six or seven per cent. of the coating is used, even when the cell is complelely run down. The expansion of the peroxide of lead in becoming sulphate perhaps blocks the coating up." By experiments, conducted by Dr. Gladstone, and the late Mr. Tribe, 32 per cent. of the total paste was found to be active material. Any way we may look forward to improvements in cells which will

increase their capacity manyfold, and already some advance has been made in this direction. Claims are put forth for the increased capacity of the Lithanode plates.

The following tables are copied from an able paper, read before the Society of Telegraph Engineers and Electricians on March 10th, 1887, by Mr. Desmond Fitz-Gerald, and they are given here, as they may prove of interest:—

TABLE I.

STORAGE CAPACITY OF VARIOUS SECONDARY CELLS.

Name of Cell.	Per lb. of Pb.		Per. kilo. of Pb.		Authority.
	Foot lbs.	Watt hours.	Kilogram-metres.	Watt hours.	
Planté	12,000	4·52	3,664	10	
Faure	18,000	6·78	5.495	15	
E P.S. L plates ...	48,000 (?)	18·09(?)	14,600 (?)	39·8(?)	Howard
,, R ,, ...	36,080	13·6	11,010	—	(?) Hospitalier.
,, S nominal 22 lb. cell ...	31,800	12	9,540	26	Fitz-Gerald
Elwell-Parker (old form)	6,633	2·5	2,018	5·5	Prospectus.
Lithanode battery (old form) ...	39,798	15	12,110	33	Fitz-Gerald
Lithanode battery "Union" cell...	47,170	17·8	14·671	39·16	G. Forbes.

TABLE II.

WEIGHT PER HORSE-POWER-HOUR CAPACITY OF VARIOUS SECONDARY BATTERIES.

Name of Battery.	Elements only. Lbs.	Elements only. Kilos.	Cell complete. Lbs.	Cell complete. Kilos.	Authority.
Planté	...	...	396	180	Reynier.
Faure	...	...	88	40	Faure.
	...	...	165	75	Sir W. Thompson.
,, (old model) ...	...	...	198	90	Reynier.
,, (new model)...	...	...	134	61	
E.P.S. L plates	...	...	133	60·4	Prospectus.
	...	...	110	50	Reckenzaun.
,, S ,, ...	66	30	135	61·3	Fitz-Gerald.
Reynier — Zinc. posve	50·6	23	117·5	53·4	R. Tamine.
Reynier — Planté form	105	47·6	...	...	*Idem.*
Lithanode battery (old form) ...	42	19·1	76	34·5	Fitz-Gerald.
Lithanode battery "Union" cell	42	19	70	31·5	G. Forbes.

Mr. Fitz-Gerald doubts the accuracy of Mr. Howard's results, which he thinks are due either to error or to the methods employed.

This well-known experimenter has recently made great improvements in plates to be employed in

secondary batteries, which largely increase their storage capacity. The improvements consist in treating the plates with magnesium sulphate, and in the method of constructing the plates themselves, by consolidation; the result being that the active material on their surface can be increased indefinitely without incurring any loss of its conducting qualities. These processes are patented. The author has the permission of Mr. FitzGerald to describe an experiment, made by him, which indicates the result of the $MgSO_4$ (magnesium sulphate) treatment.

EXPERIMENT.

"Two couples (**A** and **B**) formed of lead plates, with immersed surface $3'' \times 2''$; **A** in dilute sulphuric acid of s.g. 1·17; **B** in half saturated solution of $MgSO_4$.

"Couples charged for two hours, with reversals when gasing freely.

"**B** plates removed from $MgSO_4$ electrolyte and immersed in dilute H_2SO_4 (s.g. 1·17).

"Circuited consecutively on an electric bell (wire resistance 11·5 ohms). The following results were obtained:—

"**A** rang bell for 3·2 minutes.
"**B** " " " 19·5 "

"The difference may be made enormously greater in favour of **B**."

The experimenter remarks that by this treatment every pound weight of the battery has a storage capacity

of 1·66 ampère hours, and a discharge-rate of 10 ampères. Mr. Fitz-Gerald has also made some experiments with $PbSO_4$ and Pb_2SO_5 ($PbSO_4 + PbO$) in order to ascertain which of these compounds is more easily reduced by an electric current. Contrary to the general opinion, he has found that the latter substance is easier to electrolyze than the former.

In practice, when the higher sulphate forms on the positive plates, there is great difficulty in getting rid of it. This would naturally give rise to the supposition that it is not easily decomposed by the current, and it is possibly true when it exists in a battery. This apparent difficulty to reduce the higher sulphate in practice may be due simply to a difference in its conducting properties, and not to difficulties of reduction.

We have seen that, as charging proceeds, the s.g. of the acid becomes denser, and the E.M.F. rises. Let us now examine this question. Water is a very bad conductor, and dilute H_2SO_4 a good one; therefore, the weaker the acid, the worse the conducting qualities. If the dilute acid is strengthened by adding H_2SO_4 until it becomes very much concentrated, the conducting properties become worse; but this stage is never reached in accumulator work. Kohlrausch gives the following table for the specific conductivities of an electrolyte made with water and sulphuric acid.

s.g. at 18°c.	Conductivity at 18°c.	per cent. in sol H_2SO_4
1·1036	5084	15
1·1414	6108	20
1·1807	6710	25

The arrowheads show direction of increasing conductivity.

It will be observed that, since the solution is put into the cells at 1·130 or 1·170, the mixture is approximately a 20 per cent. solution, or one part concentrated H_2SO_4 to four parts water (in practice, one part to five) ; and again, since the s.g. at the end of a charge rises to 1·180 or 1·200, the solution is about one of 25 per cent., and its conductivity is about 10 per cent. better.

Great care is necessary in mixing the solution. A large vessel must be employed, by preference, of lead with burnt seams. The acid should be poured into the water slowly, and cautiously, because the temperature of the liquid rises to a high point, and splashes might do serious injury, even producing blindness. The water must never be added to the acid. It is always safest to obtain the solution ready mixed.

A well-charged cell is found to have about half the resistance of a discharged one. This is due partly to the difference in the conductivity of the electrolyte, as explained, and partly to the surface of the plates being in a better conducting state when charged. The sulphate of lead is a poor conductor, and when higher sulphates form, which often is the case when the plates are discharged, an enamel of a very bad conductor is produced in patches, diminishing the active surface of the plates, and very difficult to reduce. By active surface is meant that surface upon which the current can do useful work.

Certain advantages exist from the fact that the resistance of the cells grows less as charging proceeds. Were this not the case, with a dynamo giving constant E.M.F. for all currents within its capacity, it is evident that the charging current would rapidly grow less as the charge approaches the end. It does diminish, but not in any great degree if a shunt dynamo is used, although the counter E.M.F. may have risen as much as 20 to 25 per cent.

The necessity for keeping all the connecting strips short and of low resistance, the junctions clean, and the cables short and large, may be illustrated by an example. Suppose a set of fifty cells, with a normal charging current of thirty ampères, which has an E.M.F. of 110 volts. Since the fifty cells themselves give 100 volts, this acts as counter E.M.F., *i.e.*, in opposition to the charging current ; thus 10 volts is the true pressure which forces the thirty ampères through the accumulator, so that the total resistance for cells, cables, and connections is about one-third ohm. This is considerably increased if the connections are not clean, or the cells not placed close together to shorten the lead connecting strips as much as possible, and the cables large. It will also be observed that, if the charging current were raised to say 112 volts, a much larger current would flow, since the forcing power would be twenty per cent. greater. It is evident also that the rise of E.M.F. in the cells, as charging advances, must materially reduce the effective margin of pressure, notwithstanding the lower resistance of the cell. The methods

of regulating charging currents will be dealt with in a separate chapter.

The next point to consider is why boiling occurs. It must be clear that, as the surface of the positive plates becomes converted into lead peroxide, the material to be acted upon by the current grows less and less, the plates become virtually smaller; and, consequently, the current becomes too large, resulting in decomposing the water of the electrolyte, and often warming it considerably.

However, in practice it would not pay to gradually reduce the current as the charge advances; therefore it is not done. Yet it can be experimentally shown that, by reducing the current in exact proportion to the diminishing active surface of the plate, boiling never occurs, and hundreds of ampère hours may actually be added beyond what is accomplished in the usual way. In fact, an infinite charge in point of time, but finite in quantity, might be given if the current is continually reduced to suit the lessening active surface of the positive, since the total quantity becomes the sum of a special form of an infinite series. Boiling does no harm unless the paste is loose, when much material will be removed by the agitation of the liquid.

Frequent and prolonged over charging, with currents about 30 per cent. below maximum, is the only way to reduce the higher sulphates of lead, which are apt to form when the cells are allowed to run too low. Such sulphates are most obstinate to reduce, and the least speck remaining indicates that more will form, almost

like a growth of mould ; so that when this is observed, overcharging must be resorted to. These higher sulphates then fall off in scales or powder, for want of adherence to the healthy oxide forming beneath them.

It must be borne in mind that the addition of caustic soda, or of the other materials mentioned, in a great measure prevents the formation of these higher sulphates.

If, when the cells boil, the charging is stopped for half an hour or more, and is re-started, it will be found that boiling does not recommence for some time; and this process may be repeated again and again. When boiling takes place a kind of gas battery is produced, both positive and negative plates being covered with a layer of gas. When charging is stopped, this gas escapes or becomes partly absorbed, so that the plates are once more exposed for a short time to the current, before the phenomenon recurs.

If too large a charging current is used for the area of the plates, buckling is likely to ensue, and very rapidly if any bad sulphate is present on the positives. Then, short-circuiting, due to plates touching one another in the liquid, soon takes place. Buckling is due to unequal expansion of the plates, and even under the best treatment, this trouble arises if the makers have not given them a proper form. The paste expands on discharge and *vice versâ*; therefore, it is absolutely necessary that such expansion and contraction should be symmetrical over the whole surface. These continual changes in the volume of the paste, after a time, loosen it from the grids ; but, if these are uninjured,

repasting can be resorted to. With judicious treatment, some years may elapse before this becomes necessary, and it is applicable chiefly to the positive plates. The difficulties which may arise with the negatives will be commented on later. Buckling may also spring from other causes, to be considered in the next chapter.

It might be supposed from the above remark that, when boiling, due to the current at this time being too great for the active area of the plates, commences, the risk of buckling the positives may occur. However, this is not so, because the case is not the same as when the surface of the plates is actually smaller : there is still a large surface upon which the current can do its work, but, instead of forming PbO , it decomposes the water of the electrolyte.

It is often necessary to give prolonged charges in order to remove any white sulphate that may form. In these cases the current should be reduced, say to two-thirds or half the maximum ; otherwise much paste may be removed. It must be well understood that overcharging improves the plates at all times, and *never* injures them.

From time to time water must be added to the cells so as to keep the plates well covered. It has already been explained that, for the first few times, acid solution s.g. 1·130 or 1·150 should be employed to keep up the level ; but, if at any time the s.g. or the electrolyte falls below the normal, then the acid solution is again used until the normal is once more reached. It is, therefore, most desirable to place an acidometer in every cell, in

order not only to indicate the s.g. of the liquid, but that, by its rise and fall, a fair estimate of the state of the plates (*i.e.* storage) may be arrived at. For instance, if the acidometer in a cell refuses to rise, then a careful examination must be made, as something is at fault; most probably two plates are touching. Again, if the apparatus rises slower, during charging, in one cell than in others, or if it should fall more in it than in any others at other times, then a leakage is taking place in that cell, probably due to one or more pieces of paste sticking between some of the plates.

When the accumulator has been in use for a long time and the plates have become very well formed, the s.g. of the electrolyte does not rise so much as it was accustomed to do in previous stages, and the nature of the boiling appears somewhat different. The gases then given off, although considerable, do not produce such a milky appearance of the liquid as formerly. However, no harm is to be feared from these phenomena.

It is of the greatest importance to keep the charging current within the permissible maximum at starting, by methods to be described.

The plates in cells, no matter of what kind, should be so arranged that the resistance from every part of one plate to every corresponding part of the adjoining plate shall be equal; otherwise buckling will take place. The plates should also be so framed that they cannot shift.

There is no better test for ascertaining the condition of the battery than by the colour of the plates.

When it is first started, the negatives are a yellowish grey, and the positives dark brown, spotted with a whitish substance. If the first charge is carried on long enough, this whitish material disappears, being the objectionable sulphate deposit ; and from this time the colour becomes the test.

The positives should be dark red, chocolate, or plum colour ; but, when fully charged, they look like wet slate, nearly black. After a small discharge, they regain their former appearance. If too much discharged, the white deposit reappears in patches. The negatives soon assume a pale slate colour, which darkens slightly as the charging advances. They are, however, always much lighter than the positives. The upper edges of the positive plates generally appear grey, but this is of no consequence if limited to those parts.

It is possible to become a *connoisseur,* in regard to the colour of the plates ; for a constant observer can tell the true condition of the plates, not only whether they are in good or in bad order, but also the exact amount of the charge they contain.

The following remarks apply to the unpasted plate type. These plates, as before mentioned, require occasional reversing, which is a most delicate operation. The charging current at these times requires to be very small at the start, and to be increased as the operation advances. Unless these precautions are taken, the plates scale, and the cells become short-circuited. So far, such cells have not proved much of a success with the public, on account of these troublesome reversals, which

have to be made several times after leaving the factory.

Notwithstanding the losses necessarily incurred by the use of an accumulator, the latter is an economy in private installations, and no doubt, eventually, for public supply. There is no need to run the engine and dynamo during the many hours, when only a few lamps are required, and the plant may be smaller. Besides, the light is never cut off for a moment, day or night; and a feeling of security exists from the knowledge that a breakdown need not be feared. Another advantage is, that during the cleaning of machinery, or slight repairs, there is a sufficient reserve to ensure light over the span when darkness would otherwise ensue, at great inconvenience to the household.

The following table of lighting hours has been drawn up by Mr. R. E. Compton and is most convenient for reference.

LIGHTING HOURS THROUGHOUT A YEAR OF 8,764 HOURS.

Daily Lighting.	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sep.	Oct.	Nov.	Dec.	Total per Annum.
From Sundown to 11 P.M.	218	173	160	126	99	80	87	114	144	180	207	233	1821
,, ,, 12 P.M.	249	201	191	156	130	110	118	145	174	211	237	264	2186
om 6 A.M. to Sunrise... ...	63	36	7	...	...	...	...	...	...	13	43	63	254

It will be noticed that the hours from six a.m. till sunrise, and from sunset till eleven p. m., for the whole year are 2,075, or, say, in round numbers, 2,000. These figures are a guide to the number of hours during which one or more lamps are required.

CHAPTER IV.

DISCHARGING.

FOR pasted plates the discharge should not exceed four ampères per positive plate, in a cell of the E.P.S. L type. This is at the rate of 6·1 ampères per square foot of positive plate. Returning to our old examples: For a 15-plate E.P.S. or E.P. cell, 28 ampères should be the maximum current for discharge; in a 23-plate cell, 44 ampères; and in a 31-plate cell, 60 ampères. The discharge may, therefore, always be larger than the charging current; and this is often an advantage. Moreover, it is found that the larger the discharge, the lower the internal resistance of the cells at the time; so the accumulator, to a great extent, becomes its own governor. This is a remarkable property, and may be brought to mind in this way: there is practically no fall of E.M.F. for any discharge within the limits allowed, because the internal resistance of the cells diminishes as the current increases. But for this property, batteries could not be employed for practical purposes, because their efficiency would be too low, and a regular pressure could not be obtained without much trouble and risk of failure.

The current starts at one point in the circuit, and returns to the same point; but, in its course, it gradually loses pressure, *i.e.*, E.M.F. Therefore, the pressure of the current differs at every part of the circuit; and its fall is in proportion to the work it is doing at that part of the circuit.

Since the E.M.F. of one cell is two volts, of two cells four volts, and so on, it is evident the total E.M.F. is only obtained between the ends of the battery. When testing one or two cells, low E.M.F. measuring instruments, or, as they are generally called, voltmeters, are employed. But such instruments would be destroyed, if used to measure a high E.M.F.; and one made to measure high E.M.F. would be unsuitable for low pressure, except in combination instruments, which are really equivalent to two separate voltmeters. It is with a low E.M.F. voltmeter that the state of each cell is examined.

If, in any cell, the pressure is below 1·9 volts, then it requires charging, for the residual charge has been reached; and, if the other cells are charged, it must be cut out of the circuit during discharge, and replaced when charging is renewed. Only, the connections are altered for the time being, the cell not being moved.

There must always remain about 25 per cent. of the total charge the cell is capable of taking; otherwise troubles arise, so that the moment the E.M.F. of the battery falls below an average of two volts per cell, which indicates that this limit has been reached, charging must be resorted to.

When the plates are nearly discharged, that is, far below the minimum permitted, nearly all the paste on the positives is in the form of $PbSO_4$. This soon decomposes into the higher sulphates which ruin the plates, and, apart from other consequences, cause them to buckle when charging is proceeding. It is, therefore, evidently essential to keep a residual charge sufficient to give an E.M.F. of two volts per cell. In fact, after being fully charged, the cells may be steadily emptied to the permitted limit, giving practically two volts per cell the whole time. Then comes a rapid fall of pressure, soon reaching zero point.

Too quick a discharge buckles the plates, and a very sudden large discharge drives the paste out of them, although the current may be well within the maximum. Therefore, when motors are started, it should be done through a variable resistance, apart from the requirements of the motors themselves. For the same reason, large batches of lamps should not be simultaneously turned on. Quantities of gas, driven from the plates at the moment of sudden, heavy discharges, cause the injury. A large sudden discharge may be regarded roughly as one of 30 per cent. of the maximum.

Should a cell in the battery be dead, *i.e.*, give no E.M.F., from overwork, then, if not attended to at once, and cut out of the circuit during discharge, the outgoing current will pass through it and start charging the cell in the reverse direction, thus converting the positive plates into negatives, and *vice versâ*. This will naturally destroy the cell, because, when charging is commenced,

the opposite action takes place; and, eventually, the plates sulphate, buckle, and lose their paste. A dead, worked-out cell will also produce a counter E.M.F. of two volts. The total loss of pressure will therefore be that of the cell itself, plus its counter E.M.F.; in other words, a cell, giving no E.M.F., lowers the pressure on the circuit, equivalent to the removal of two good cells. But, if it be dead by reason of plates touching, or be short-circuited from any cause, the loss of E.M.F. will only be that of the cell itself, as it sets up no counter E.M.F. in this case.

In order to give a general idea of the storage capacity of cells in practice, a 15-plate E.P.S. or E.P. cell may be taken as an example. This is found to be 330 ampère-hours available, and, since the maximum discharge is 30 ampères, it is evident that such a discharge can last for ten hours, and still leave the required residual charge. If the discharge is at a lower rate, then, of course, the time occupied in emptying the cells will be proportionately longer.

It is usual with accumulators to measure their capacity in "ampère-hours." An ampère-hour means one ampère flowing for one hour.

As for cells of the unpasted type, no remarks are necessary regarding their discharge. The only limit is when the E.M.F. falls considerably, on increasing the discharge.

CHAPTER V.

FAILURES: THEIR CAUSES AND REMEDIES.

THIS part is probably the most interesting to the majority of those who possess installations, because the batteries are generally put up by the makers. The theory has not an interest to everyone, but, when difficulties arise in daily working, energy is at once called for.

There are two troubles which beset most accumulators, viz., buckling of plates and bad forms of sulphating. To these all other difficulties, with few exceptions, may be traced. Buckling is almost unknown in well-managed installations.

When cells are left to rest for a long period, they should be thoroughly charged; and, once a month afterwards, a good charge should be given them. This will keep the plates from sulphating, which arises from total discharge by leakage and local action, always present in a small degree. If by any chance the positive plates should sulphate, which is shown by the chocolate colour turning greyish all over the surface, or in patches, the action must at once be stopped, or the battery will be spoilt.

The colour of the edges of the plates gives an indication of what is taking place over their surface; so that, if there is not a marked difference in colour between the positive and negative plates, a careful examination should be made. The results of bad sulphating are scaling, the falling out of paste, buckling, and short-circuiting, and, in the last case, the grids generally become rotten; while the causes may always be traced to the acid solution being too weak or too strong, but more generally to the cells having been habitually discharged too much, or left standing for a long period with little charge in them. Short-circuiting naturally will do this also, since the plates become discharged. A leakage in the circuit may discharge the battery, without the knowledge of the user. Bad insulation of the cells themselves will produce the same result.

An easy test for the insulation of the accumulator is to wet the back of the hand with weak acid, and place it against the shelves; should the insulation be faulty, a pricking sensation is felt, which becomes painful if 100 volts are used. Should higher voltage be employed, it is not safe to make this experiment. At 200 volts the shock is strong, but varies with every individual; for some people do not object to 210 volts, whilst others cannot stand sixty, especially those who suffer from damp hands.

All currents may be regarded as dangerous to the person after 250 volts, but the pressures of 60 to 100 volts, which are harmless under ordinary circumstances, may prove highly dangerous under

peculiar conditions. For instance, a man may be on a pair of steps placing a new lamp in a fitting, and unexpectedly get a slight shock, due to leakage or otherwise, and then the start it gives him may cause a fall from the steps. It is, therefore, always advisable to cut both leads when anyone is attending to fittings, or doing any work on the circuit.

To return to the cure for sulphating, a continual charging below maximum rate, half to start with, for a prolonged period, will gradually reduce the unhealthy sulphate to the healthy form (*i.e.*, Pb_2SO_5 to $PbSO_4$), and finally charge the plates by conversion of the $PbSO_4$ to PbO_2. The task is tedious, but it must not be hurried, or the positives are certain to buckle. Most of the white sulphate will fall off in scales, but should any stick between the plates it must be pushed down with a piece of wood or a flat strip of ebonite, which is the best. But on no account should a piece of metal, or any other conducting substance, be employed for this purpose. White sulphate is a very bad conductor, so that the exposed surface of the plates in the battery is much reduced by its presence. The maximum charging current is, therefore, too large; but the current may be increased as the white substance falls off or disappears. If the sulphating has become very bad, these scales often separate from the plate with the blocks of paste which they overlie. This is very vexatious, for the capacity of the battery becomes much reduced by loss of active material; and great trouble is experienced in getting from between the plates these pieces, which, if not removed, short-circuit the cell.

In the most recently improved cells, in which the plates are placed farther apart, the paste will occasionally stick between the plates, although it would appear at first sight to be impossible; so that absolute reliance must not be placed upon the statement of the makers that paste *cannot possibly* stick between the plates. It may occur in three ways. The first is, when the plates are in bad order, they frequently lose their flatness; and, consequently, the original distance between them is no longer maintained. The second is that some samples of paste are apt to throw out short crystal needles, which entangle the paste in its fall. Finally, the opposite blocks of paste may so fall as to encounter one another.

It frequently happens, when a battery is first erected, that very large scales come off the positives. The plates in new cells must, therefore, be watched for a few weeks; and any scales that may be observed should be removed from between the plates. If this is done carefully, the trouble soon disappears.

A good plan is to clear a little of the deposit off each positive with a stick, and so offer some healthy surface to the current, lowering the resistance of the battery, and facilitating the reducing process.

Where the fault is great, the best plan is to clean the battery properly. After bad sulphating the capacity of the cells must always be less, in consequence of the loss of some of the active material. The cleaning of a battery consists in removing the sections from the cells, separating the sets of plates, and scraping the white deposit off the positives. There is no need to remove the plates from the lead strips, for by bending them

apart plenty of room is allowed for manipulation. In cases where the plates cannot be parted, they must be reached as well as circumstances permit; and generally no difficulty occurs. The wire brush material, sold under the name of carding, will serve to do the work satisfactorily. A piece of this is cut to six by four inches, and nailed to a block of wood an inch thick. The brush is now applied to the positives till they appear their proper colour, and they are finally washed with the electrolyte, and on no account with water, or sulphating will set in immediately. This done, the cells are again made up, and new solution is employed. They are then ready for immediate charging, and they should be regularly overcharged and watched for some time. The cells also should be cleaned from any deposit. The old acid answers well for washing the plates with, and for placing the negatives in whilst waiting; for these, being wet, are injured by exposure to the air. (The old acid may finally be used to destroy weeds on roads and paths, so that nothing need be wasted.)

There is considerable risk of accident from short-circuiting, if a cell is moved with the electrolyte in it. Therefore, unless skilled labour be employed, it is best to syphon off the liquid with a three-eighth red india-rubber tube, filled with solution by dipping it bodily into a vessel of liquid and then keeping the thumbs over the ends to prevent escape, whilst it is applied to the cell. Under no circumstances should the tube be sucked in order to "draw the syphon," as this proceeding is highly dangerous; because of the poisonous and corrosive character of the acid and the liability to receive a

shock in the mouth. So long as the electrolyte touches the plates there is possibility of short-circuit. This must, therefore, be drawn off completely, and then no accident can possibly arise.

If the positives are past recovery, it is cheapest to have a new set, which can be obtained from the makers at a very moderate cost in exchange for the old plates.

The process just described for cleaning a battery is employed for buckled plates, with the difference that these require to be straightened. This is effected by placing thin boards between every positive plate (or negative, if at fault), so that all the plates are parallel, and in the same position, as when in the cell, or the connecting strip of lead will be bent. The plates, with the interleaved boards, are then laid on their side, upon the ground, and pressed till they are quite flat. A portable lever-press, or a screw-press, is generally used for this purpose. No attempt should be made to flatten by means of hammering, as this is sure to loosen the paste. As soon as the battery is reconstructed, charging should be commenced.

When the negatives are removed from the cells, they, on drying, become hot; and this is probably due to the finely divided lead they contain oxidizing in air.

Negatives exposed to the atmosphere for a length of time, especially if it be moist, show signs of blistering in use. This is very troublesome, for the blisters frequently become detached in the form of scale, which sticks between the plates, thus partially short-circuiting them, and eventually causing the positives to sulphate.

Blistered negatives often exist which do not drop the scale, and, in this event, no evil consequences follow; but the risk should not be incurred. With new cells the negatives often blister, from careless manufacture. If a cell becomes completely exhausted, or by chance reversed, the negatives buckle ; but, as a general rule, it is only the positive plates which are subject to this trouble.

It is always advisable to charge well before cleaning or straightening plates, because the air does not then act so prejudicially upon them.

If the positives sulphate, the surface becomes very hard ; but, when in good order, the surface of the paste, as well as that of the grid, is soft ; and the colour comes off readily on the finger, like pigment.

When the positives get into a very bad state, the negatives are generally in a similar condition.

Much loose scale, from positive or negative plates, may be removed by taking the sections apart and agitating the sets of plates, separately, in a cell of liquid.

Buckling, apart from the causes indicated in the preceding chapter, may be produced by too high a charging or discharging rate. It also often arises from pieces of loose paste sticking between the plates, which cause an unequal resistance between the surfaces, so that expansion and contraction are not symmetrical. When this occurs, the plates are often of a good colour. In all cases the framework, or other means employed to keep the sections together, must be so made as to allow for the expansion of the positives. The allowance need be very small, since the plates are generally put together in the

expanded condition, *i.e.*, in the unformed state; but slight after-variations should be taken into account. Sometimes, plugs of paste drop out when everything appears right, and the cause is usually found to be that a large discharge has been taken suddenly. Therefore, this proceeding should be avoided.

If a film appears all over the inside of the cell, partially obscuring the plates, the water mixed with the acid has been impure. When this occurs, much inconvenience arises from inability to see the edges of the plates properly; but no actual harm is done, and it can be entirely avoided by allowing the solution to settle after mixing, and baling it out, leaving the sediment undisturbed. A slight quantity of powder, at the bottom of the pots, will always be found: this consists chiefly of the white sulphate, removed during the first few chargings.

With ordinary care the author has found that, in cells two years in use, the loss of paste is so small as hardly to be worth mentioning. Some experimenters have, for the same period, found a considerable weight of deposit at the bottom of the cells. It may, therefore be concluded either that the battery was not properly managed, or that the plates were faulty in their manufacture.

The plates must never touch the bottom of the cells. Consequently, be careful to observe occasionally the condition of the bottom block or frame. A temporary cure for plates buckling is to insert glass strips or wooden wedges, to prevent adjoining plates from touching; but

the cause must be removed at the first opportunity, and the plates straightened.

It sometimes happens that the dynamo leads have been wrongly connected, in which event the plates throughout the battery become reversed; the negatives change to chocolate in colour, and the positives to slate. Such a mistake ought to be carefully guarded against. Should it occur, there is only one remedy, namely to discharge the battery completely, through a resistance frame or through the lamps, so that the maximum discharge allowable is never exceeded. This resistance may be reduced as the E.M.F. becomes less. When the accumulator gives no E.M.F., or a very low one, the dynamo wires must be correctly joined up, and charging should be started very slowly at first, and with a resistance, for a time, in one of the dynamo leads to keep the current small; since there is little or no counter E.M.F. to overcome till the cells charge up in the right way. Running the dynamo slowly will answer the same purpose as the insertion of a resistance, but the latter is more convenient. It will take a long time to get the plates into good order again, and perhaps many troubles will ensue, each of which must be treated in the proper way; but matters soon mend, provided the mistake be discovered early.

A resistance frame, called, for brevity, "a resistance," consists of a frame of wood with a number of coils of iron, german silver, or platinoid wire stretched across it. The whole contrivance appears like a frame, containing a large number of spiral springs placed close together. The

frame is sometimes made of metal, in which case the coils are insulated from it by means of porcelain supports. Arrangements exist for permitting the current to flow through one or more of these coils, so that the opposition to the current may be varied at will. The wire is proportioned in its section so as to carry the desired current. Such a frame is shown in the plate of the Goolden and Trotter governor, illustrated in Chapter V., Part 2.

Platinoid wire possesses so many advantages that its properties ought not to pass unnoticed, because of the high resistance it has. German silver wire has been used on account of its high resistance, but this property in platinoid is almost double. This alloy does not oxidise in air, and its resistance for various temperatures is fairly equal. The wire is also very strong and its cost no greater than that of german silver. Therefore, it is evident that, for any definite resistance, far less platinoid wire is required than if german silver were used. The word platinoid would seem to imply that platinum is present in its constitution, but this is not the case. There is a small amount of tungsten in the alloy. Its melting temperature is high, which renders it very suitable for use in resistance frames.

If a cell gives no E.M.F. from any cause, except complete short-circuit, then the discharging current has the effect of charging such a cell the reverse way, and the plates become reversed. The proper course to pursue is always to disconnect such cells when discharging, by bridging them over with a wire and to reconnect when

charging. In time, the cell will become charged equally with the rest, and it can then be permanently replaced. It is unnecessary to cut both connections of such a cell; one end is sufficient. Proceed in this way: disconnect the positive strip of the dead cell from the negative of the next, and clamp one end of a wire to the negative strip of the dead cell (equivalent to positive of the adjoining one) and join the other end of the wire to the negative strip of the next cell, which has just been disconnected.

When the charging commences, be careful to remove this wire before connecting up; otherwise, the cell will be short-circuited through it, damaging the plates and perhaps causing an accident by fusion of the wire, if the latter is too small. The whole operation may be facilitated by the use of a two-way switch, with a break between the contacts, suitably connected, by which means the cell can be put in and out of the circuit at pleasure.

All conductors in the accumulator house should be so placed that, if the insulation wears off by the action of the acid and of the fumes, short-circuits will be impossible. The leads may be carried on porcelain insulators, and every wire should be kept apart in all cases.

Never add concentrated acid to the cells, as the grids will soon become rotten, if this is done. Never test a cell for E.M.F. by "flashing," which means taking a short wire, placing one end firmly on the positive strip of a cell and rapidly touching the negative strip, in this way producing a flash, if the cell has life. It is the old method of testing, which soon spoils the cells, if

frequently resorted to; and no scientific result is obtained. The proper way to test is with a lamp or voltmeter, as before described.

When the plates are sulphated, the internal resistance of the cells is greater, and, consequently, the E.M.F. for daily use is much lower. Their capacity, also, is less. Charging continued till boiling occurs, without further observation, may result in erroneous conclusions, for clearly the less the capacity of the plates, the sooner will the phenomenon occur, and everything is supposed to be in good order; whereas a serious fault may really exist, for the plates may be in bad condition, or much paste lost, or many cells dead. The boiling in the latter case arises from the charging current being too great, since much counter E.M.F. has been removed. Again, it may happen that no amount of charging causes the cells to boil, indicating that nearly all the paste has fallen from the plates. Even in this condition, the cells act as regulators to steady the light; but they have scarcely any capacity.

If, at any time, the plates of a fully-charged cell are removed from the electrolyte, then, on making up the cell again, the s.g. of the liquid put in should be the same as it was before. If acid of a lower s.g. is used, no amount of charging will appreciably raise it, because the plates being chiefly composed of PbO_2 when charged, there is little or no $PbSO_4$ which can be converted to PbO_2. Consequently, but a very slight further chemical action can take place in the electrolyte.

At all times when a cell is charged as much as

possible, whether the plates are in good or bad order, a point is arrived at when the acidometer indicates no further change in the s.g.

Till recently the grids were made of lead ; now an alloy of lead is employed which is much harder. Many advantages arise, but there is one which claims particular attention, and that is the possibility of repasting the plates when required. The first expense of a battery is so large, and the renewal of the whole of the plates in the cells so expensive, that it pays the owner to repaste his plates when it becomes necessary. With proper attention and fair usage, years may elapse before this is required ; but the manner of proceeding is described for the benefit of those who may wish to act upon the suggestion. The value of the process may be estimated when it is stated that the author had a battery of fifty-four cells which lost most of the paste, and its capacity became very small. The whole accumulator was repasted by unskilled labour, for an expenditure of about ten pounds, the result being that the battery was as good as new. Sometimes only a cell, here or there, wants renovating, instead of the whole set.

Proceed as follows : take the sections to pieces and spread the plates a little, when the construction admits of this being done. Start with the positives, and mix up a stiff paste of red lead and H_2SO_4, one part commercial acid to two parts water. The paste eventually assumes a dark reddish-brown colour, and more acid must be added until all appearance of red lead is gone. We then have a paste chiefly composed of $PbSO_4$. It is

possible to buy $PbSO_4$ pure, and it is well to do so, since it is purer than a mixture of red lead, which generally contains much carbonate. The spreading of the plates allows the hand to reach every part of each grid. The paste is best laid on with a small wooden board, and the surplus scraped off with a piece of iron hooping. The plates are now bent back to their normal position, and set aside to dry. The paste should then be perfectly hard and adhering; if not, its consistency is at fault. A few trials will determine the point. A twenty-four hours' drying in a moderate temperature is sufficient; the plates are then finished. The negatives are treated in the same way, only the paste is made with litharge. The sections are now made up, placed in the cells, and all is made ready for charging. Probably thirty hours or more will be required to form the plates, after which every hour of charging is storage, when the chocolate or plum colour of the positives and the familiar appearance of the negatives are soon attained. Sometimes the forming is far more rapid.

Repasted cells must be cut out, during discharge, until they boil; and in no case discharge a repasted battery till all cells boil.

It is possible to paste the positives with PbO_2, purchased under the name of puce-coloured lead, in which case ready-formed charged plates are made at the start. It is found by many persons that the PbO_2 paste fails and soon falls out; but this has not been the experience of the author. There is a physical difference between pasting with $PbSO_4$ and PbO_2. In the first case, the

substance is laid on in the expanded form, and in the latter in the contracted state. If the manipulator can succeed with PbO_2, there is great saving, since the cell is ready for a small discharge at once. Repasting can only be accomplished with economy when the grids are not rotten.

Indiarubber, if of good quality, does not deteriorate in the acid ; but, if bad, it falls to pieces in a short time ; indeed, even a few hours may break it up.

It may be of importance to some persons to know the best means to adopt when it is desired to transport a battery to a distant place, so that the plates may not be injured. The sections should be taken apart, and the plates pressed together ; so that only one face of each of the end ones is exposed to the air. Each batch can then be wrapped in oiled brown paper. When it is not possible to follow this course, the sections should be kept from contact with the air, as far as possible, by enveloping them in oiled paper, the interval between them being stuffed with hay packed in oiled paper. When the battery is put up again, it is treated in the same way as if it were a new one. If this method of transporting be adopted, no harm will be done to the plates; but it will be advisable to set the cells up again as soon as possible.

A new form of spray averter has recently been introduced by a well-known firm. It consists of pounded cork floating on the surface of the electrolyte. The chief danger connected with the method is, the probability that the cork will eventually become carbonized

by the action of the acid, and consequently become a feeble conductor. This would be serious if the level of the liquid fell sufficiently to allow the cork to touch the plates. Moreover in time the cork will become "water-logged," and settle between the plates. At one time petroleum was floated on the electrolyte to keep back the spray, but any complete spray preventer appears to injure the plates in course of time.

There is little to be said regarding unpasted batteries; for, beyond clearing any bad scales which may cause short circuits, and occasionally straightening buckled plates, there is nothing to be done.

So much has been said in this chapter on failures that it might be supposed that an accumulator was simply a source of annoyance. This is the case only where the accumulator is not watched, and any little fault at once remedied. As a rule, very little trouble is given, and none at all if competent persons occasionally view the installation. In order to bring all the facts concisely before the reader, the following summary is added.

CHAPTER VI.

SUMMARY.

ALWAYS charge the cells until they boil well. Never allow the battery to run down till its E. M. F. is below the average of 2 volts per cell. If this should occur when it is known that the charge is not low, an examination of every cell should be made. The acidometers in the cells give an approximate idea of the state of the charge, if they are intelligently observed. Examine the plates every few days, by observing their colour, and other characteristics. No current meter is of service to measure the charge remaining in the accumulator, since this instrument takes no account of the leakage which occurs before reaching it, nor of local action. As soon as only 25 per cent. of the total charge remains in the cells, the E. M. F. rapidly falls, on further discharge. Precautions should be taken to guard against too large a current flowing when charging is commenced by inserting a resistance, or by means of an automatic governor ; also provision must be made against lamps being injured when they are turned on during charging hours, or the moment charging is completed.

The instant any fault is noticed, it should be remedied at once; and any dead cell cut out immediately. Do not charge longer than necessary, but see that all the cells boil well: if any are much behind, observe if there is any obvious cause for this. One hour of over-charging is advisable. Occasionally examine the insulation. Observe that the liquid in the cells does not become warm during charging. All measuring apparatus should be compared with standard instruments periodically, so as to avoid falling into errors which may prove destructive to the plates. Feel all connections and switches every now and then, to see if they become warm.

Do not take advice for a remedy from the last person who gives it, before receiving an assurance from some competent authority that there is value in the suggestion. Amateurs often act in the former way, and generally the result is that a heavy penalty has to be paid, but unfortunately not by the individual who caused the mischief. Possessors of an accumulator should not, at any time, spare money in sending for competent persons to set any fault right, for an apparently trifling matter becomes very serious in a short time, and by the course suggested much good money is saved and vexation avoided. Above all, it must be remembered that no rules unmixed with brains are of the least service.

INSTALLATION.

PART II.

CHAPTER I.

ENGINES, DYNAMOS, ELECTRICAL MOTORS, AND THEIR TREATMENT.

THE first consideration is the prime mover, which may be worked by steam, gas, hot air, water, petroleum, or wind. For installations up to 25 or 30 lamps, a hot-air engine may be used, but in such cases by far the larger number are worked by gas engines, on account of their simplicity and the small amount of attention required. Besides, no boiler is necessary, there is no extra insurance to pay, and no risk of any kind encountered. The "Domestic, or Davey, Motor" is good in some instances Where water power can be obtained all the year round. for no payment, it is the cheapest power of all. Our attention will be confined to gas and steam engines, because these are the most common motors employed. For large installations steam has so far proved the best,

because till recently gas engines of large power have not been so satisfactory or so reliable as steam engines. But now great advances have been made.

The Otto patents will shortly expire, and the manufacture will soon enter a stage of competition. This is beginning to show itself already. As a result, the present holders of these patents, Messrs. Crossley, have woke up to the changed condition of things and are making great improvements in this class of engine. They are adopting the tube igniter and many other additions, which render large gas engines practically as good as steam power. For domestic work, it is rare that a gas engine larger than a 9 h. p. nom. is required.

Taking gas engines first into consideration, the 9 h. p. Otto, by Crossley, gives about 18 h. p. indicated; but since about one-fifth of the indicated horse-power is absorbed in working the engine, the useful or brake horse-power should not be reckoned over 14 at the most. But it must be remembered that gas engines give off very variable powers from time to time, depending upon the condition of the exhaust valve, temperature of the cylinder, quality of the gas, gas pressure, and other causes. It is, therefore, safe to expect, on an average, from such an engine, only 12 h. p., or say one-and-a-half times the nom. h. p. for useful daily work. In estimating the power, the makers assume that the gas employed is about 17 candles. With gas of higher candle power, considerably more work can be got out of the engine; and it may be pointed out that the diminution of horse-power between 17 and 14 c. p. gas is far less than

between 20 and 17 c. p. gas. There are very few places in England where gas is given of a higher illuminating quality than 18 c. p., and probably in no district worse than 14. In some places in the North of England and Scotland the gas has an illuminating power of 27. The smallest Otto engine, excluding toys, is the half h. p. nom., which gives a large ind. h. p. for its size; and one h. p. may be taken as its useful power. After the one h. p. nom., which is also advantageous for its size, all others may be taken on the average as giving a brake h. p. of one-and-a-half times the nom. h. p. of the engine. The manner of working a gas engine, whether an Otto, Atkinson, Stockport, Bischoff, or any other type, will not here be described, because clear and simple instructions are sent out with these engines. But a few suggestions may be made to show how, with certain modifications, they may be adapted for the special requirements of electric lighting. These engines are almost universally in use at the present time. The following remarks will apply to the Otto engine, but they are applicable almost word for word, equally to other types.

Gas engines are liable to stoppage, but this defect may, with proper precautions, be reduced to a minimum. Extra large oil or grease-cups should be put on all bearings and moving parts. Every place, where oil is generally dropped in from time to time, should have automatic grease or oil-cups. In short, the engine on being started ought to carry sufficient oil for a twenty-four hours' run, even though not more than

eight hours is likely to be required. For the crank, oil is recommended in preference to grease. The circulating water tank, when employed, should be extra large. To avoid the danger of the slide, when this exists, sticking or "cutting up," the springs or other arrangement in use on the back cover should be as free as possible. The chance of the slide light blowing out is thereby increased. Therefore, an additional protected burner should be placed in such a manner as to relight the slide light in case of such an accident. A long fine jet answers the best, because the actual source of the flame may be six inches away from the slide, and out of danger from any puff which may come from it.

In the modern type of gas engine, this slide and slide light are dispensed with. Thus the greatest trouble attending a gas engine is removed. A small and simple valve is substituted, which, at proper times, establishes a communication between the cylinder and the inside of a red-hot metal tube, kept at this high temperature by means of a Bunsen flame, which is outside it, and consequently quite out of reach of the gases within the cylinder. This ignition apparatus is termed "the tube igniter." In the Atkinson engine there is no valve, but the gas mixture reaches the heated part of the tube only when compressed. These tubes burn away, and till now had to be replaced every few days. But there is in course of manufacture an improved tube which is likely to last some months. These renewals cost but a few pence, and, considering the security they give against a breakdown, they would be cheap

at even a higher price. The worm-wheel gearing has now taken the place of the bevel-wheel gearing, thus removing the main source of noise in this gas engine. Also, in these improved types, the governor is made much more sensitive, the mechanism is simpler in construction, and the tendency to "hunt" is eliminated. The setting of the valves to start the engine is far more convenient and practical, and all moving parts likely to be dangerous are well protected by cast iron covers. Improvements have been made in many other details. The chief omission, as regards safety to the attendant, appears to be that of a suitable guard on the frame at the crank end, to prevent the possibility of the foot being placed within reach of the crank when the engine is started. Serious accidents have arisen from this cause, and it is strongly recommended to the owners of these engines that they should fix such guards at the first opportunity. Fig. 13 shows the improved form of the Otto gas engine. Some makers use an electric spark to ignite the gas in the cylinder. This method is not new, but owing to many former difficulties, it has only recently met with success. The chief advantages arising out of this plan are a saving of gas for the slide light, and no gas fumes in the room where the engine is placed.

It is better to start a gas engine in the ordinary way or with an electric motor, than to have a "self-starter," which is a dangerous piece of apparatus.

The tight side of the belt to the dynamo should be on the floor side, which avoids the possibility of the belt

rubbing on the floor when it wears slack; this often happens where the belt is placed near the ground. When no other method is available, the difficulty may be got over by making a gas engine run the reverse way, for a very small cost, if so desired.

After a definite run, pre-determined upon, there are

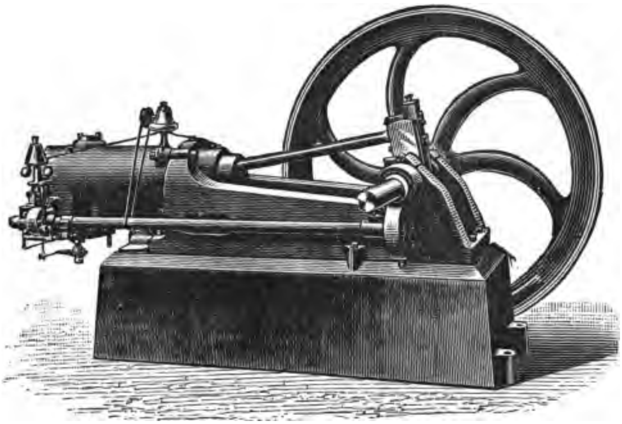


FIG. 13. OTTO GAS ENGINE.

many good ways of cutting off the gas supply, electrically and mechanically: Mr. Cunynghame's home-made apparatus is one of the best. A common clock is used with a weight in the place of a spring. This weight falls a certain distance per hour, and placed behind it is a scale marked in hours. The weight, on reaching the bottom of the scale, or zero point upon it, comes into contact with a lever; the clock-weight continuing to fall, and pressing upon the lever,

causes it to move and to discharge a weight which turns a tap, cutting off the gas supply to the cylinder and slide light, and stopping the engine in consequence.

To set the apparatus, the discharging weight is set, and the clock weight pulled up till it reaches a number on the scale corresponding to the number of hours the engine is to run. The engine and clock are started together.

To avoid the recoil, which occurs with gas engines on stopping, and which causes the brushes of the dynamo to be injured by the armature running the reverse way, it is desirable to have a tap fixed in the place of the screwed plug intended for the indicator, and to open the tap on turning off the gas, thus preventing the air or gases in the cylinder becoming compressed, so that no recoil occurs. The time-device could be made to carry out this additional requirement.

Figure 14 shows a Spiel petroleum engine.

It will be observed that this petroleum engine is similar to a gas engine, with the addition of a reservoir on the top; and at the side a small centrifugal hand pump, which is used to fill the reservoir from the benzoline store, this liquid being used instead of ordinary petroleum. From the benzoline, in the reservoir, the cylinder is fed with gas; a special form of spray pump, worked by the engine, is used to convert the benzoline into gas.

There is another well-known petroleum motor, the Priestman engine, wherein common petroleum is employed.

Mr. Yarrow has lately been experimenting, and successfully, upon the possibility of using petroleum vapour in place of steam, in the common steam engine.

With all forms of petroleum engines a good ventilation must exist in the room where they may be placed, and all leakage of petroleum and its vapour must be prevented. Otherwise, should a light be brought into the room, a serious explosion may occur, or this result may even be produced by the slide light of the engine.

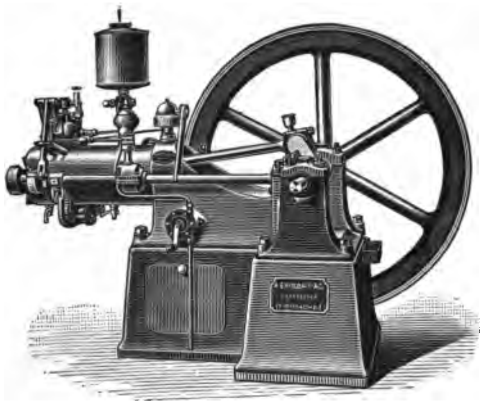


FIG. 14. SPIEL'S PETROLEUM ENGINE.

Steam engines, in the same way, should have very complete oiling arrangements, and money should not be spared in making all bearings adjustable. The boiler should have two methods of being fed with water, a precaution which often avoids a breakdown.

The Fromentin Automatic Feeder (which is shown

in figures 15, 16, and 17) is a safe and convenient way of keeping the water-level in the boiler constant, without attention; and it relieves the driver, as well as the owner, from much anxiety. The feeder consists of two large vessels, B B, balanced like a pair of scales; the pivot A carries a rotating set of ports shown at C (Figs. 15, 16, and 17), and D represents the fixed ports, so that

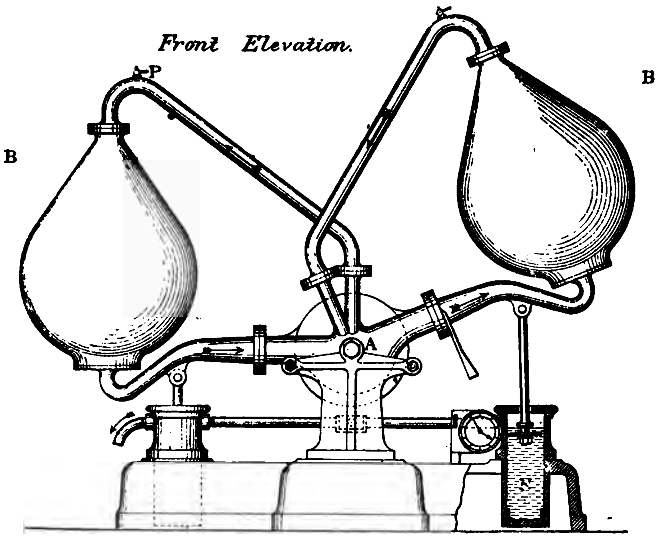


FIG. 15. FROMENTIN BOILER FEEDER (ELEVATION).

each vessel is put in connection alternately with the boiler and the supply tank. Take a working cycle to show the action. The vessel which is down, or lowermost, has its lower end connected with the feed pipe of the boiler through pipe J (Fig. 16), and the upper end in

communication with a "dip-pipe" leading from I (Fig. 16), which enters the boiler and ends about one inch below the correct water-level. The other vessel has its lower end connected with the supply tank by the pipe G, and its upper part is in connection with a pipe which dips into the supply cistern through H. About six or eight feet of water pressure ought to be employed, and the

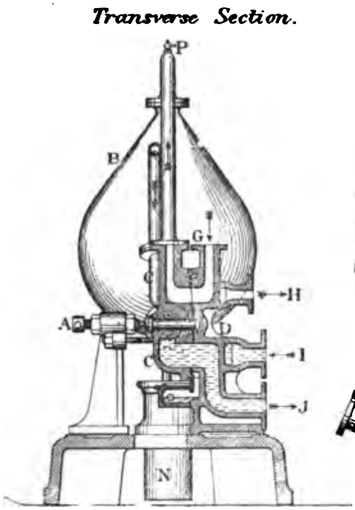


FIG. 16.
FROMENTIN BOILER FEEDER
(SECTION).

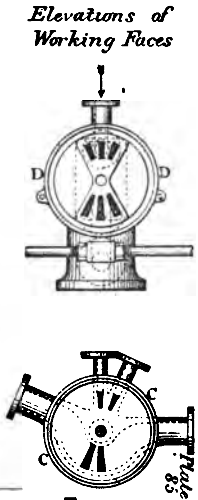


FIG. 17.
FROMENTIN BOILER FEEDER
(PORTS).

feeder should be at least three feet above the boiler water-level; but it is not necessary to place the feeder over the boiler: it may stand away from it on a shelf. When the vessels are in the positions described, and the dip-pipe is covered with water, both are filled with liquid, and, being balanced, remain stationary, the boiler water

circulating through the vessel which is in communication with the boiler.

When the level of the water, in the boiler, falls, the dip-pipe becomes exposed, the equilibrium is destroyed, and the lowermost vessel empties itself into the boiler, steam taking the place of the water. Now, the difference in the weight of the two receptacles causes the other to descend by gravity and to place itself, by means of the changed positions of the ports, in connection with the boiler to be discharged when required. The vessel just filled with steam fills with water from the supply, and the steam escapes from its upper end into the tank, thereby heating the water supply. The feeder, therefore, possesses the advantage of also being a feed water-heater. The rate of feeding must naturally vary, but, generally, the movements take place about every three to five minutes. It will be observed that the whole of the motions are done by gravity. To prevent a shock at each turn, dash pots are employed, shown at N in the figures; air taps, at P, are used for starting the apparatus in the first instance. A counter also is usually fixed. The only attention this apparatus requires is occasionally to clean the ports and tubes from incrustation.

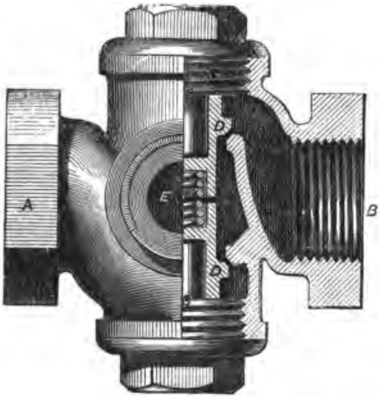
The heating of the feed-water is an important point. Much scaling of the boiler is avoided, straining of the boiler plates through extremes of temperature is prevented, the steam pressure more constant, and fuel saved.

A new paint has been brought out by Mr. Henry

Crooks, C.E., which should be largely employed for all bearings, both of engines and dynamos. It is vermilion in colour, but as soon as its temperature is raised over 100 deg. Fahr. the colour alters, and, at about 150 deg. Fahr., becomes dark brown. On lowering the temperature, the original colour is restored; and these changes may be made an unlimited number of times without altering the properties of the pigment, which is said to consist of a mercuric compound. For protection this paint may be varnished over, without altering these pro perties. For moving parts, which cannot be touched, in order to observe the temperature, except at some risk, such an indicator is invaluable, and it may also be used to show whether electrical conductors are over-heating, since 150 deg. C, is the highest temperature to which conductors should be allowed to rise. It is only necessary to paint a small patch on every part liable to heat, so that a pound of paint would do the work of a dozen installations. There are a few more desirable additions which are of great value for engines used for electric lighting purposes.

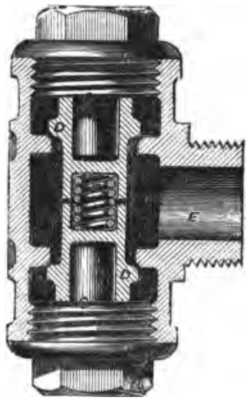
Everyone is aware that, unless the cylinder cocks are attended to on starting, at times during running, and on stopping, there is great risk of the cylinder ends being blown off by water collecting in the cylinders, when relief valves do not exist; and generally these are added only on very large engines. All danger may be avoided by the use of a very pretty little contrivance (shown in plates 18 and 19) consisting of a casting with three outlets A, B, and E, containing two small valves

D, D with a spring between them. Two of these outlets A and B are connected with the ends of the cylinder, in place of the blow-off cocks, and the third E is led to a drain. The screw plugs, shown in the diagrams, give access to the valves. The whole time the engine is running the valves work automatically, and the one



SIDE ELEVATION
HALF IN SECTION

FIG. 18.



CROSS SECTION

FIG. 19.

AQUAJECTOR.

DESCRIPTION.—**A. B.**Connection with either end of Cylinder. **C.** Screw Caps for cleaning, examining, or removing valves. **D.D.** The Valves which allow water to escape every stroke of the engine. **E.** Exhaust connection. **F.** Spring, which opens both valves whenever the engine stands.

connected to the end of the cylinder under no pressure is opened at each stroke, thus allowing the condensed water to escape. When standing, both valves remain open, so that both ends of the cylinder are allowed to drain;

Cylinder cocks may also be added, if thought necessary. In the course of a five years' trial, there has been no failure of the apparatus; nor has any examination been required. As far as the author is aware, this apparatus, called the Aquajector (Figs. 18 and 19), is made by only one firm, viz., Messrs. Bailey & Co.; and, the price being almost nominal, its adoption ought to be general.

There is also a very convenient form of fusible plug, introduced by Mr. Williams, which renders unnecessary the use of tools to replace or test the plug at any time. Since the new fusible parts cost only 6d. each, the expense of renewals is reduced to a minimum without sacrificing efficiency. The boiler insurance companies accept these plugs, which, therefore, may be regarded as perfectly reliable.

In all installations, oil is a large item of cost, especially under the slovenly and wasteful system of storing and using generally in vogue. By employing Richter's Economisers (see Fig 20), a great saving is effected, and much oil may be used two and three times over by fitting a filter to the economiser. The latter consists of a reservoir and pump in a compact form. This apparatus is inexpensive, and soon saves its cost.

Pans should be placed at all points where oil running through bearings can be caught, and this waste oil should be placed in a separate economiser for future use, but must not be mixed with the new oil.

In speaking of these various contrivances, it is intended not to advertise the articles, but simply to

indicate some valuable resources available to those who may, perhaps, for want of them, be working at great disadvantage. An expenditure of from five to ten pounds will add the whole of these improved apparatus to a small or large installation, with the exception of the Automatic Feeder.

A self-oiling sight-feed lubricator ought invariably to be used for lubricating the cylinder. The use of tallow and fats should be avoided. All mineral oils are good, such as Engelbert's, Ragosine, Asbestoline, and the

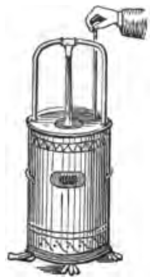


FIG. 20. OIL ECONOMISER.

like. Grease for bearings is far more convenient than oil, and much cleaner. Grease cups, if fairly large, require replenishing but once a month, so that the engine always stands ready to start. There are many greases in the market, but after trying, during considerable periods, some ten samples, by various makers, English, American, and foreign, only one has proved useful for every purpose—heavy and light bearings, and fast and slow running shafts. This is supplied by, Messrs. Elwell Parker, and is remarkably cheap.

Experience has shown that 5s. worth of this grease goes as far as £5 worth of oil, and the friction is in no way increased by its use. At starting, it is only necessary to adjust the grease supply for keeping the shaft cool. When this is once done, no further regulation or attention is ever required beyond refilling the cups; and their indicators show exactly the amount of grease left in them.

As this book is dealing only with private installations there is no need to go into the details which apply to large works. However, a private installation is here supposed to go up to 3,000 lamps, this being considered a very wide margin, because the largest country house rarely requires over 500.

Engines used for electric lighting should have automatic governors, which "cut off" and thus "expand" in proportion to the load. It may be taken as a rule that engines of the best manufacturers can be worked continuously to three times their nom. h. p. with economy, at maximum boiler pressure. Cheaper engines are not strong enough to stand a continual strain of more than twice their nom. h. p. The maximum power, given off at any time, is clearly proportional to the steam pressure.

It is always safest, in practice, to adopt the following method; in purchasing a steam engine required for a particular installation. Allow eight 16 candle lamps per brake h. p., when the engine-house is within 100 yards of the residence; if farther off, seven to the to the h. p., but never less, because by making the leads

larger this condition can always be obtained, excepting under peculiar circumstances, which would arise only in the event of great distances intervening between the generation of the current and the place where it is used, when it may be cheaper to light fewer lamps per h. p. than to have larger mains.

In making the calculation, consider the maximum brake h. p. of the engine one-and-a-half times the nom. h. p.; there will then be no chance of falling short of power, and a good reserve of power is obtained by raising the steam pressure slightly, when more work is demanded. The boiler should always have a larger nom. h. p. than the engine, in order to secure a good steam supply, and to allow longer intervals between the fueling. The higher the pressure of the steam, the more is expansion possible, and the greater the economy in coal, since the large amount of fuel required for converting the water into steam, which is rendered latent, is not required a second time for further raising the pressure; and all heat (with a trifling exception) is available for useful work.

Expansion beyond a certain point is best accomplished by the use of two or more cylinders, such engines being called compound. But these engines are not recommended for private installations, unless there is skilled labour, because the simpler the engine the less likelihood of its getting out of order. The same remark applies to all high-speed engines, although, in confined situations, these are often indispensable. One hundred revolutions per minute of the fly-wheel suffice for

all purposes in engines from ten to twenty nom. h. p., and 150 per minute in smaller engines. After twenty nom. h. p. the fly-wheels turn slower. All these engines come under the designation of slow speed.

Much talk is made of saving fuel by the use of higher expansion, but to the private installer it is not of much consequence, for the saving is generally more than counterbalanced by the extra expense of locomotive tubular boilers, compound engines, and so forth, which require more attention than the Cornish multitubular boiler and simple engine. There is also more anxiety due to higher boiler pressures.

To obtain an actual idea of the saving effected by the use of a compound engine, as compared with a simple engine, take coal at 20s. a ton, and for an installation of 100 lamps used 2,000 hours in a year, supposing 6 lbs. of coal per ind. h. p. per hour are used, for simple working, and 2 lbs. for the most economical compound methods; and the result would be £75 to £80 a year. On the other hand, there must be at least £30 to £40 allowed for faulty boiler tubes, drawing them for cleaning, keeping all fittings steam-tight against the high pressure of the steam, increased interest, and so on. But this is an exaggerated case, for in no 100-light installation would it be possible, in practice, to light up to a maximum of 2,000 hours a year. The actual saving, under the most economical method, probably would not be more than £20, which is a very small proportion of the total cost. Although 2 lbs. of coal is stated by some makers to give 1 ind. h. p., it may

be questioned if, in fact, it can be done under 3 lbs. The risk of breakdown is far less with lower pressures and slow running engines.

It is strongly recommended that the boilers be insured against explosion, and against collapse of flues; and also that the engine driver be insured in respect of injury, or death, consequent upon such accidents. The premium is very small, and as the company insuring makes periodical inspections, all risk, legal, moral, and pecuniary, is taken off the owner. To give a rough idea of the cost, take a boiler of twelve nom. h. p. used with an engine of 10 nom. h. p., and working, with greatest economy, at 36 ind. h. p. This can be insured in the Boiler Insurance Company, of Manchester, for £2,000, including the engine driver; and the premium in respect of both will be about £5 a year. The insurance covers all damage to buildings and to machinery caused by an explosion, also compensation to the driver in case of injury, or to his family, in the event of his being killed. It is, therefore, well worth while to take this precaution. If the engine-house is made of incombustible materials, there is no necessity to insure against fire.

When the engine is worked daily, much fuel is saved by banking up the fire at night, instead of drawing it, since the water is kept hot for the next day. This is a perfectly safe proceeding, if an automatic feeder be employed. There should be two water gauges and two safety valves, placed on the boiler, to permit of perfect inspection and safety. Suitable boiler composition should be employed to prevent

scaling ; and, in order to obtain the right kind, it is advisable to have an analysis made of the water. Indi cating apparatus ought always to exist, by which means the working parts of the engine may be examined in a scientific manner periodically ; and thus undue mechanical and electrical waste can be checked.

We may now turn to the counter-shafting and belting. Clutches are generally preferred for electric lighting machinery, to fast and loose pulleys ; because they occupy less space, and are more easy to work. Any good belting answers the purpose, provided there be no raised joint. Chain belting, made of leather links only, has been much used, but is most undesirable, when combined with iron or steel links, because they gradually saw the connecting pins asunder. In any case, periodical examination should be made so as to observe the state of the links. Sampson's belting is expensive, but it is one of the best in the market, and will last indefinitely. Another kind of belt comes from America (Cooper's), and it is sold in London. This leather has at least twice the strength of the ordinary material, and it grips exceedingly well ; but for double belting it might be found to stretch, when large powers are transmitted. Contrary to the ordinary practice, this particular belting must be placed with the face side nearest the pulley. When counter-shafting is employed, it is best to drive it by double belting, and carry single to the dynamos. Fly-wheel centre to shaft centre, about 15 feet, is the best distance. Belts should not be too tight, and the sag should be given at the upper, not the floor side : the advantage is, besides

avoiding the possibility of rubbing on the floor, a better grip round the pulley, with better tension. Belt syrup, free from resin, should be used, if slipping occurs when the tension is correctly adjusted and when the load is not beyond the power of the engine. Occasionally in the sag of the belt, a wave is produced, which is reflected in the lamps by blinks. This wave can generally be avoided by making the machinery firmer, and sometimes, when this fails, by slightly raising or lowering the speed of the engine.

Counter-shafting should be solid, and all arrangements made so that the belts may run horizontally, which permits of their being left slack, utilising their weight for the tension, and saving the bearings from undue wear and tear. It is best, when space permits, to place, respectively, the engine and dynamos on opposite sides of the counter-shaft; the belt tensions then balance one another on the counter-shaft bearings, and much friction is prevented.

The action of oil in the bearings is peculiar. The shaft and brasses never come into actual contact, oil always intervening, no matter what the load may be; so the friction really consists of shearing a thin surface of oil. It is thus seen why the "friction load," which means the power employed to run the machinery free, is about the same when a load is added, however great. The condition is, that oil or grease shall always be supplied to make good the loss. Hence, if the indicated horse-power, to run free, requires, say, four-horse power, and a load of one horse-power is added, the indicated

horse-power will be 5; and so on. It is evident, therefore, that the greater the load put upon an engine within its power, the greater the efficiency. In fact, such an engine, in practice, would require almost the same quantity of coal and undergo the same wear and tear in lighting one lamp as probably ten lamps; for this work would be very small as compared with its friction load.

In the engine-room a speed indicator is always to be found. The general form of this instrument necessitates the use of a watch with a seconds dial, and the indicator must be applied to the moving shaft when the observation is taken. To render the taking of speed more convenient, a counter has been brought out in the United States under the name of Heath's Patent Self-timing Registering Speed Indicator. The apparatus is, in appearance, very similar to those in general use; but it contains a watch-work which runs half a minute at a time. It is wound up by pushing in a stud, and started by pressing another button, the former action also setting the hands at zero. The counter is applied in the usual manner to the end of the shaft, and, when the operator is ready, the starting button is pressed, which permits not only the train to run, but also the hands to rotate. At the end of the half minute the hands cease to move, although the spindle may still be in movement, and the reading indicates the revolutions during a minute.

Having now discussed many questions which are often either not understood, or neglected by unprofessional

persons, it becomes necessary to look into the mechanical details of dynamos and electro-motors, leaving, for the present, electrical questions proper.

There are endless patterns of dynamos in the market, but all those of the best makers give approximately the same efficiency, and possess the same qualities generally. The slow-running dynamo, say from 500 to 700 revolutions per minute, should be chosen, since there is less vibration, and less wear and tear with these than with machines speeded up from 1,000 to 1,500. The slow-speed machines, however, are more expensive. It is imperative to have solid foundations, and, for the bearings, self-oiling arrangements ; nothing answers this purpose better than grease. The machines must be kept perfectly clean, and should not be tampered with. For the mechanism, all that requires attention are the commutator and brushes. Both must be kept scrupulously clean, and sparking in any form should be guarded against. All modern machines have the brush holders adjustable, so that full directions will be given for producing the best results. The commutator soon becomes worn by sparking, or by too heavy a pressure of the brushes. When much wear takes place, the truth of the commutator becomes destroyed : instead of wearing down equally it gets eccentric, and assumes all manner of shapes. Re-turning in the lathe is then the only cure ; but this irregular wear can be almost entirely avoided ; in which case the armature need not be removed for turning more than once in three or four years, if as often. If any plates in the commutator are softer

than others, or contain flaws filled with solder, then nothing will prevent the unequal wear, except by substituting good plates for bad ones. Rolled copper is the best material for commutator plates; it wears evenly, keeps bright, and contains no flaws.

It should be well borne in mind that, if the commutator is not kept in good order, the loss of efficiency may be enormous ; and, eventually, it will be impossible to use the dynamo. In addition, the least unequal wear causes the brushes to jump, making the light flicker, and the faulty places become worse daily. When faults are confined to one or two plates, they are termed "flats."

Five things must be attended to for preserving these parts in good order :—

1. The brushes must have a proper inclination.

2. The pressure should be adjusted properly.

3. The lead must be given correctly for the current.

4. Occasional application of oil or grease to the commutator should be resorted to.

5. Scrupulous cleanliness, in regard to the brushes and commutator, must be observed.

1. The brushes, in most cases, may be more inclined as they are pushed further through their holders. The inclination is right when the commutator runs smoothly under them without noise, and they should offer a good surface to conduct the current. When new brushes are inserted, they must have their ends ground, or filed, to the curve of the commutator. This is best done by clamping a brush in a vice, between two pieces of wood,

so as to avoid spreading the plates, or wires, during griding or filing. Unless a good surface of contact exists between the commutator and the brushes, it is often difficult to obtain a current from the machine. When the commutator wears out of truth, the inclination must be increased.

2. The pressure need not be great, but only as much as is necessary to ensure perfect contact during running: more than this is unnecessary so long as the commutator runs true. Great heating of the commutator and armature is often due to the friction of the brushes, when too much pressure is put on.

3. The lead next claims attention. The neutral lines on the commutator are the two lines which can be drawn along the plates at the extremities of a diameter which coincides with the vertical or horizontal, according to the pattern on which the dynamo is built; and this diameter, if produced, would meet the yoke, or yokes, of the field magnets. These, theoretically, are the places where the brushes should rest; but, in point of fact, the neutral lines become displaced when a current is taken from the machine, and the displacement increases as the current is larger. To enter into the many reasons for this displacement is not within the province of this book; only the consequences will here be considered. It may, however, be mentioned, that the lead arises from the fact that the armature is magnetic, and reacts on the field magnets' magnetism in such a way that the neutral points become shifted. The less magnetic the armature, compared with the

strength of the field magnets, the less the displacement. If the brushes are not placed upon these neutral lines, sparking ensues, excepting in specially constructed dynamos. The brushes having been adjusted in accordance with instructions 1 and 2, all that is necessary to set them for the correct lead is to rotate them on the frame, to which they are attached for this purpose, until a point is reached when all sparking ceases or is reduced to a minimum. The frame is then clamped; but as this lead varies with the work done on the outer circuit, it must be set according to the amount of current taken off at any time. It is of the highest importance that the brushes should rest on plates situated at the extremity of a diameter. As a rule one pair of such opposite plates are marked with a centre punch, and if not, the owner of the dynamo can do this; for it is found, at times, to be an advantage to know the true opposites, by direct observation. Generally, finger indicators are attached to the brush holders to facilitate the adjusting of the brushes, and to ensure their being on exactly opposite sides of the commutator. In good dynamos, when the brushes are properly set and everything is clean, a point, where there is no sparking, can always be found, The angle of the arc, which is between one of the theoretical neutral lines and the actual neutral line, is called the "lead," and this may be positive or negative. In the case of a dynamo the lead is positive; with a motor, it is negative. When the brushes are advanced from the theoretical neutral lines in the direction of the rotation of the armature, the lead is positive and varies in

accordance with the current that is flowing into the brushes. When moved in the contrary direction, a negative lead is given. In the older dynamos, the lead was very considerable; but in modern machines one-eighth to a quarter of an inch is generally all that is necessary for every current the machine has been made to give. It is essential to advance or retire the brushes in order to suit the current; otherwise sparking begins when the current is much varied. Consequently, it is always best to arrange matters so that while the machinery is running a fairly constant current shall be taken.

4. The commutator, from time to time, should have a little oil or grease applied to its surface. Grease is the best, and, if made from petroleum, one application will last a day's work, provided the pressure of the brushes be light. The best way to apply the grease, is with the finger, or a piece of rag; not waste, as particles of cotton may get drawn under the brushes. At no time should grease be applied larger than the size of a pea. Inferior dynamos require frequent lubrication. Some persons use blacklead, but this is undesirable because of its conducting properties, which are sure to lower the efficiency of the machine. This substance may be employed, with alternating current machines, since the commutators do not consist of a series of insulated plates.

5. Cleanliness is essential, or sparking is certain to result: the least speck of grit is apt to start a "flat."

Copper dust cannot possibly be formed, if all the precautions mentioned have been taken; but, should any

collect, it must be carefully removed from the machine. Undue pressure of the brushes produces copper dust in great quantities by tearing away the commutator and brushes, and this damages the machine. Therefore, when cleaning the machine, the wear should be observed, and all alterations made when the dynamo is standing with the brushes raised. The lead must be adjusted while the machine is running.

It has been assumed that the machines are not of the alternate current type, because they are unsuitable for charging accumulators; and they are rarely used for private work.

If the attendant has any doubt as to whether the dynamo is acting, it is only necessary for him to bring a piece of iron near the field magnets, and to observe whether the latter are strongly magnetic; but while he is doing this he must take care not to allow the iron to be drawn out of the hand, so as to damage the machine.

It occasionally happens, though very rarely, that on starting the dynamo, the field magnets will not excite; and consequently no current is produced. A few taps with a mallet or hammer on the yoke of the magnets will set up, in the iron, a weak magnetism, the presence of which is absolutely essential in the first instance. The explanation is that the vibration, caused by the tapping, frees the atoms of the iron sufficiently to permit of the earth's magnetism, placing a large number of them in such a polar direction as to give an external magnetic indication; or, in other words, the iron becomes feebly magnetic. The failure may also arise

from want of proper contact of the brushes upon the commutator. If these two causes do not account for the dynamo not acting, the circuit on the dynamo is probably broken at some point.

The brushes should on no account be lifted while the dynamo is running. The insulation may be much injured by this action, and a bad place is made on the commutator. In large machines such an act may result in a violent, or even dangerous, shock being given to the individual. The commutator whilst running slowly occasionally requires cleaning with fine emery paper. If its condition is very bad and turning in the lathe cannot be resorted to, it may be smoothed with a worn-out file. Of course, filing does not make the commutator true, but it mends matters for the time. When cleaning the commutator, the brushes should be removed so that they do not become charged with emery or dust.

The temperature of the coils on the dynamo should never rise high enough to prevent the hand being easily placed upon them. It is well occasionally to observe the temperature of those parts which can be touched, provided the machine does not give a dangerous E.M.F. (*i.e.* over 250 volts), and the armature can be examined for temperature by a suitably arranged thermometer, or on stopping.

Many suppose that a dynamo sold to light fifty lamps cannot be used for more: this is not so, for ten times this number might be added in some cases; but the wire on the armature would become so hot that destruction of the insulation would occur, and

possibly fusion of the wire. The meaning of a fifty-lamp machine is simply that the wire on the armature

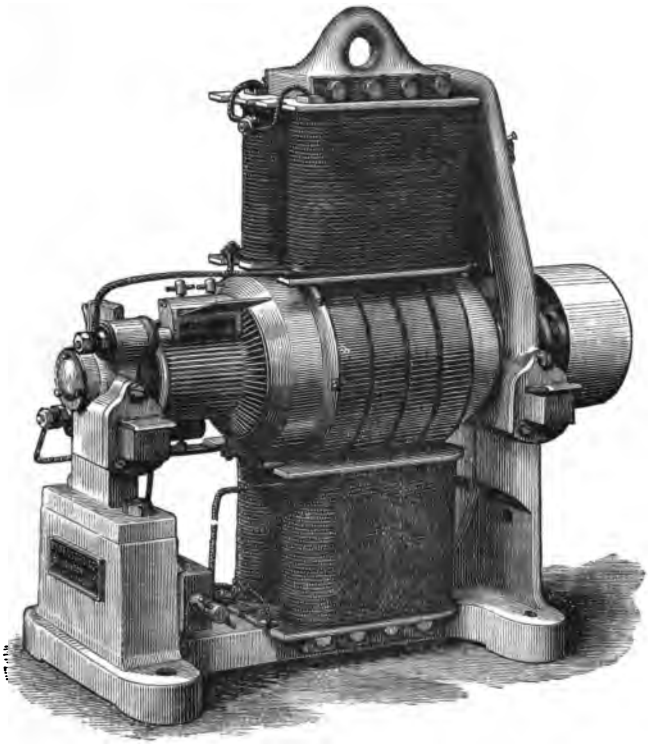


FIG. 21. SIEMENS' OLD FORM OF DYNAMO.

is only large enough to carry a current for fifty 16 c. p. lamps; so that attention is necessary to observe that this limit be not exceeded by any accident or stupidity,

such as putting fifty lamps on the circuit which may require a larger current than fifty 16 c. p. lamps.

Makers usually give the power of a dynamo in three ways: (1) lamp power, thereby indicating the maximum number of 60 watts 16 c. p. lamps the machine is intended to light; (2) by the current and E.M.F.

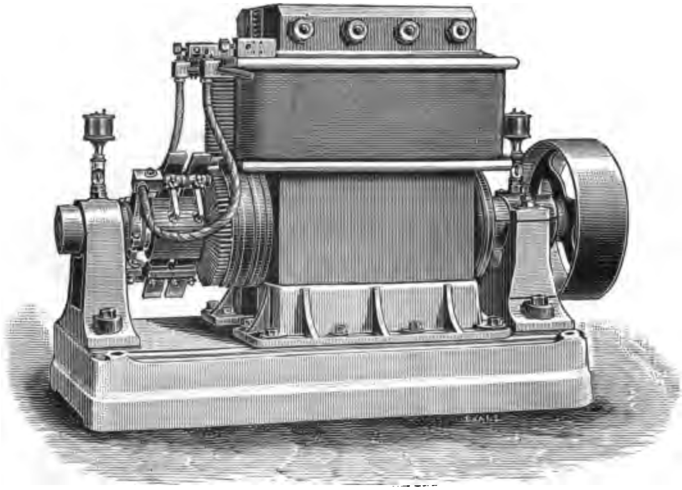


FIG. 22. SIEMENS' MODERN FORM OF DYNAMO.

it is intended to give; (3) by designating its power in Board of Trade units, one such unit being a thousand watts. In all cases it is necessary to know the pressure the machine is intended to give, in order to obtain suitable lamps to use in connection with it. The best way of reckoning the power of a machine is by units, because the carcase (*i.e.*, the frame) of any particular

machine may be wound to give any desired E.M.F.; and the units divided by the pressure give the current obtainable. For instance, a 10-unit dynamo for 100 volts will produce 100 ampères: the same carcase can be wound to give 50 volts and 200 ampères, and so on. But the speeds will not be the same in all cases.

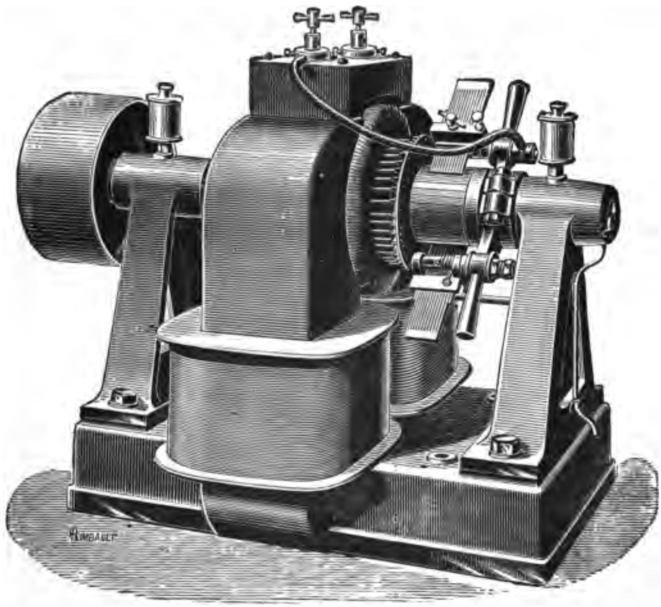


FIG. 23. PHŒNIX DYNAMO (Paterson & Cooper).

It may be of interest to some readers to be able to recognise a few of the leading types of dynamos. These are illustrated in plates 21, 22, 23, 24, and 25.

Fig. 21 represents the old type of Siemens' machine. Although no longer made in this form, except in the smallest sizes, large numbers are still doing useful service.

Fig. 22 shows the modern form of Siemens' dynamo.

Fig. 23 illustrates a Phœnix dynamo (Paterson & Cooper).

Fig. 24 represents a Statter machine specially made

FIG. 24. STATTER'S CONSTANT CURRENT DYNAMO.

for giving constant current, which is effected by the little arrangement added at the end, and visible in the plate.

It will be observed that the dynamos shown in Figs. 22, 23, and 24, are all built on one type, *i.e.*, free pole-ends uppermost; and this method is now found to be the best, and is becoming universally employed by all makers.

Electro-motors require exactly the same attention as dynamos, their construction being identical (one pattern is shown in Fig. 25), with the difference that the lead given must be negative. The speed of a motor is almost invariably higher than that of the machine it has to work, so that a counter-shaft must be employed in most cases; and this is better than worm-wheel gearing, for many machines may be worked

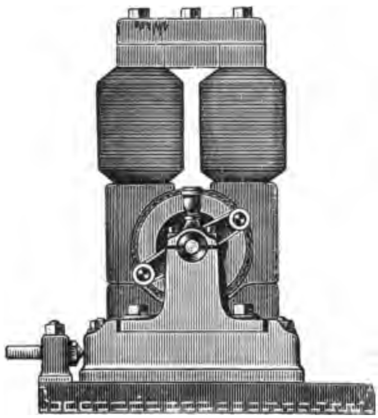


FIG. 25. ELECTRIC MOTOR OR DYNAMO.
Elwell-Parker Pattern.

off one counter-shaft, if desired. Slow-speed motors can be made, though for their power they weigh heavier than the high-speed ones. It is best, in a workshop, to have a small motor to every machine, so that each workman may have his own motor under control.

Notwithstanding that the loss between the engine and

the lathe, or other machine, is probably 50 per cent., still electric motors are economical. Heavy main shafting running all day is thus avoided. Ordinary main shafting, with the belts, probably absorb 30 per cent. of the power transmitted, especially when the alignment is faulty, which is almost invariably the case. The expense of electrical power in the first instance is no greater than the present method of obtaining power in a factory, and the difficulty of maintaining regularity of speed with motors is purely imaginary, for, in practice, no trouble is experienced on this head. To give a practical case, where the speed of the motor does become considerably altered by the variation of the work put upon it, and where it proves of advantage. When a fine light cut is taken in a lathe, much greater speed is desired than when taking a large and heavy cut. In the latter case, more power also is required. Now these two alterations in speed and power are exactly what may be obtained from a motor without any adjustment, since, in any motor, for small power, it runs faster and takes less current than when doing heavier duty. For any particular class of work, by inserting resistances with a hand switch, almost any desired speed may be had. It is best to have motors series-wound, because the field-magnets become excited the moment the current is turned on; and, in starting a motor, it is preferable not to turn the current full on at once, but gradually through resistances by means of a suitable switch. Clutches and loose pulleys are rarely needed with motors, since the starting and

stopping are more easily done by employing a switch. In cases where absolute regularity is required, governors may be used. The method, successfully tried by the author, of drawing the armature in and out of the field in the direction of its axis, has answered as well as any other system devised, the ordinary centrifugal governor being employed to produce the changes.

To start a shunt motor one brush should be raised before turning on the current, and after this is done the brush is dropped. The field-magnets consequently become

FIG. 26. MOTOR WORKING A PUMP.

magnetised before a current traverses the armature. A motor should not be started and stopped immediately, but allowed to get up its speed before switching off. This avoids cutting a large current.

It must be remembered that, although in workshops some lathes and machines are kept constantly running, the majority stand a good part of the day, not all at

one stretch, but by summing up the stoppages. At such times a motor is stopped and there is no waste,

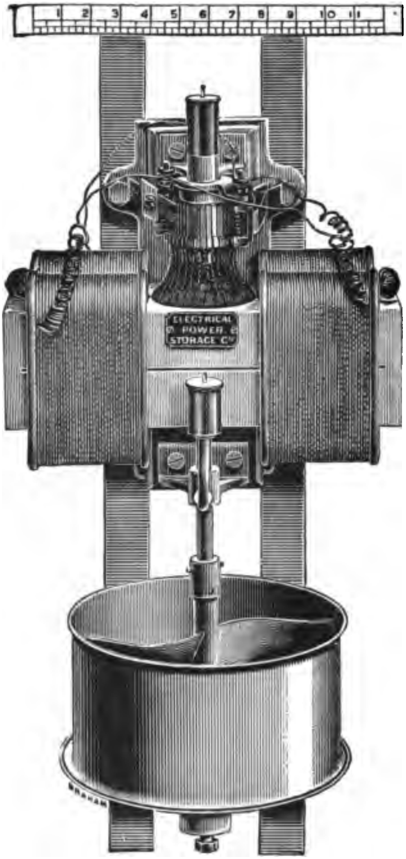


FIG. 27. MOTOR WORKING A FAN.

for the generating dynamo absorbs power from the engine proportional to the work demanded from it.

Lathes, drills, and other tools, may be moved as found convenient, without considering the position of the main shaft. This in itself is a great advantage.

In a private installation, part of the power may be used for the estate shops, churning, pumping, ventilating, or any other work ; and even for the production of cold air in summer ; in short, there is no limit to the use

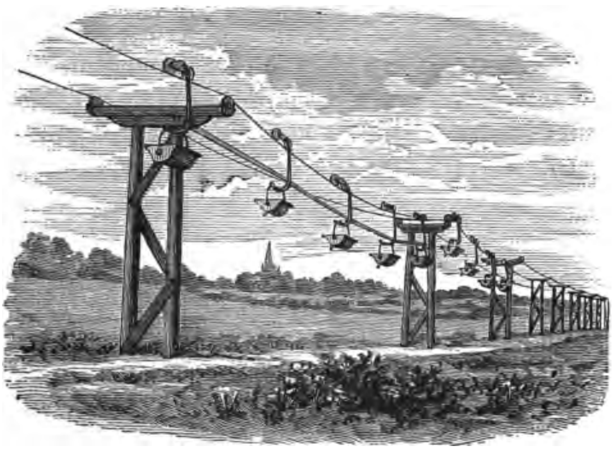


FIG. 28. TELPHER RAILWAY.

which may be made of an electric motor for household purposes, without noise, dirt, smoke, or disagreeableness of any kind.

The motor also occupies a very small space, and can be put anywhere ; for only two wires are required to lead to it, in order that it may give power. A switch only is needed to start and stop. The following diagrams will

give an idea of how a motor may be applied in some special cases.

Fig. 26 illustrates a small motor attached to a pump.

Fig. 27 represents a motor attached to a fan for ventilating purposes.

Fig. 28 shows an overhead wire railway, which goes under the name of the Telpher System. This system, in the development of which the late Professor Fleeming Jenkin took such an important part, is likely to be largely used in the future for mining and other work, especially in new countries. Without entering upon a complete explanation, it may be indicated that the motor is carried by one of the trucks, and the lines form the conductors.

CHAPTER II.

SWITCH BOARDS, SWITCHES, INSTRUMENTS, LAMPS, AND WIRING.

ALTHOUGH switch boards are not obligatory, yet, by their absence, confusion, frequent accidents, and often breakdowns are likely to occur. The apparatus consists simply of a board, or piece of slate, with all the requisite switches and instruments placed thereon, for the convenience of having all these together; so that the various positions of the switch settings, currents flowing, and so forth may be seen at a glance.

In practice, such boards are essential where smooth working is desired. Diagrams of switch boards are shown in Figures 29, 30, and 31; but naturally they must vary very much in appearance, according to the requirements of the installation.

Fig. 29 represents a switch board, made by Messrs. Woodhouse & Rawson, suitable where an accumulator is used.

Fig. 30 is a switch board, to be employed under similar conditions, on Messrs. Drake & Gordon's

pattern, the instrument at the top of this board being their steelyard ammeter.

Fig. 31 represents a simple double-pole switch board, with fuses.

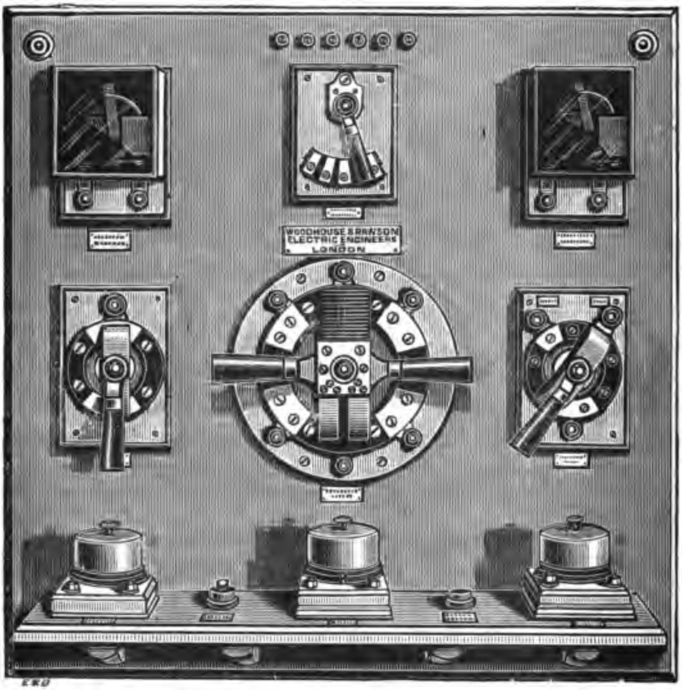


FIG. 29. SWITCH BOARD (Woodhouse & Rawson).

The chief essentials to be observed in the manufacture of switch boards are the following. The board should be of slate, by preference, and should have no connections behind. All conductors out of

sight should be extra large, and of low resistance. All connections should be made on the front of the board, by means of terminals, cone pieces, or other-

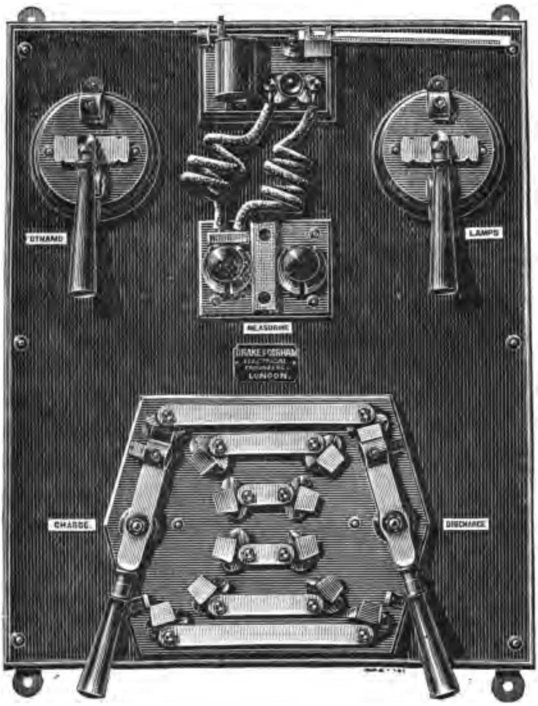


FIG. 30. SWITCH BOARD (Drake & Gorham).

wise. All apparatus fitted on the front should be capable of removal for cleaning and repairs. Switches also are best mounted on slate; the cost of slate and wood is much the same.

Wood is frequently found to be a better non-conductor than slate, due to the presence, in the latter, of metallic particles. Besides, slate absorbs considerably more moisture than polished wood, and its conducting properties, in certain weathers and damp

FIG. 31. DOUBLE POLE SWITCH BOARD.

situations, become much impaired. On the other hand, slate has the advantage of being incombustible, and incapable of warping and shrinkage. If the following precautions are taken, the disadvantages appertaining to the use of slate may be practically eliminated. The slab should first be tested, with the view of

ascertaining to what extent conduction exists. If this is *extremely* small, it may simply be due to the presence of moisture in its substance; but, if there is much conduction, the piece should be rejected. Having selected a piece of slate likely to be suitable, it should be boiled in paraffin wax, so that the latter may fill all the pores of the slate. Many firms place the slate straightway into the molten substance, and, as a result, the slate becomes very brittle. Therefore, it is better either to warm the slate before dipping it, or to place it on the paraffin wax and heat the whole together. Even with all these advantages, slate is not a sufficient non-conductor for certain classes of special work. When no leakage whatever is permissible, it is usual to cut the slate slabs and mount them upon ebonite, so that no connection shall exist between the positive and negative sides of the switch board, except across a certain distance of ebonite. Glazed earthenware may be used to replace the ebonite, when money is an object. The author has a slate switch board mounted with ebonite in the way described, and the resistance between the positive and respective sides of the board exceeds 300,000 megohms.

All switches carrying large currents should be massive. If possible, the arrangements should be such that no settings can produce accident. All switches, cut-outs, and instruments, should be fixed within easy reach. A diagram of the connections should hang alongside the switch board, for reference. In a well designed board, the dynamo leads, the house mains, and the

accumulator wires need only to be brought to it, all further connections existing upon the board itself. Before making the switch board, it is desirable to think over carefully what will be the requirements of the installation, because after-alterations are troublesome, and tend to disfigure the appearance of the board. Every terminal, or other part liable to be short-circuited, should be protected by covers of wood, glass, or

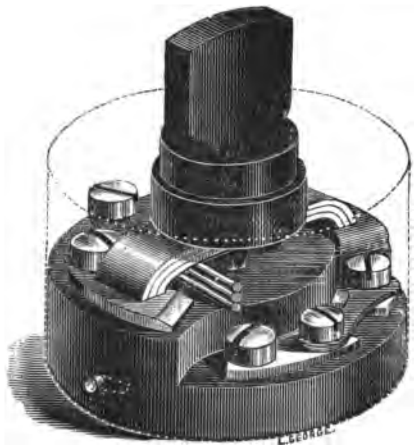


FIG. 32. WOODHOUSE & RAWSON'S LAMP SWITCH.

insulated metal. To avoid the possibility of accident, it is best to place all switches, cut-outs, and ammeters on the same lead, positive or negative, and to colour all positive parts on the board red, for easy distinction. Two glass doors should protect all boards, each door covering one polarity.

The next question is, which kind of switches shall be

used. There are cheap and also expensive switches; some are made for large currents, and others for small. The latter generally come under the name of lamp switches, and carry from one to ten ampères, according to their size. Some of the best switches, large and small, are those made by Messrs. Woodhouse & Rawson (see Figures 32, 33, 34, 35, and 36). They have every requirement which such apparatus should possess, viz., perfect contact, smooth working, incombustibility, and parts easily removed for cleaning or repair; they are also thoroughly well made, and are cheap withal.

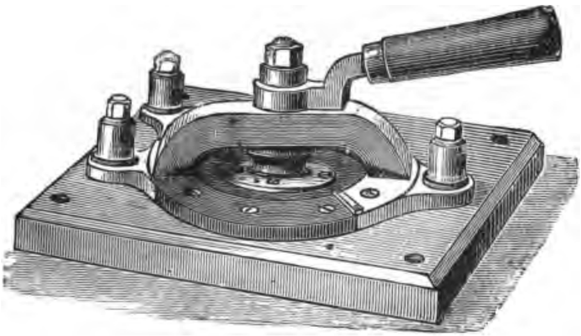


FIG. 33. WOODHOUSE & RAWSON'S LARGE CURRENT SWITCH.

Fig. 32 illustrates a quick break lamp switch, with a self-contained fuse.

Fig. 33 is a large current switch, suitable for an ammeter, since there is no break between the two contacts. If these were placed farther apart, so as to permit the finger in passing from one to the other not to touch the two at the same time, it would be suitable as a 2-way switch.

Fig. 34 is a double-pole switch, of similar construction to Fig. 32. A portion of the base is shown removed, and permits a view of the switch placed under the slate block and which is similar to the switch above it, the handle working both at the same time, and thus enabling both leads to be cut with one action.

Figs. 35 and 36 represent a switch suitable for placing in the course of a tube, as in the case of a bracket, and when a gas-fitting is converted for use with

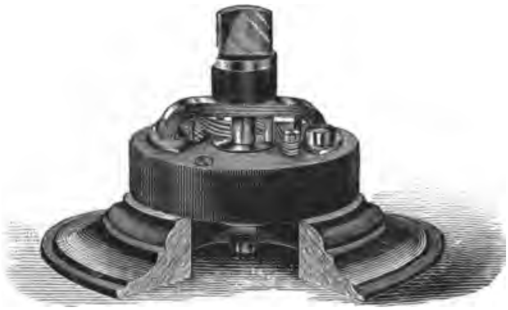


FIG. 34. D. P. SWITCH (White's pattern).

an electric lamp. One diagram gives the general view, and the other shows the interior.

Fig. 37 is a view of a 5-way switch, the current in this case passing through the axis of the moving finger. This switch can be used to start small motors, inserting, resistances by hand, and the like.

Fig. 38 shows a special form of switch, designed by the author, which will be described a little further on.

These switches, except when made for lamps, are not

intended to break the current, as this creates a spark and roughens the contacts; but special forms, in the large sizes, exist for breaking the current without injury to

FIG. 35. SWITCH FOR GAS FITTING.

FIG. 36. INTERIOR OF SWITCH FOR GAS FITTING.

the bright surfaces. When a current is put through an ammeter, no visible spark is created, because the resistance of the instrument is very small.

Fig. 39 shows a large snap action switch, this action being gradually adopted in all cases, whether for large or for small currents. By snap action is understood that, in turning the switch off in order to break the current, after

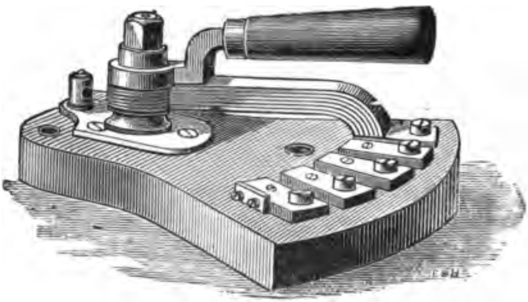


FIG. 37. WOODHOUSE & RAWSON'S STEP SWITCH.

moving the handle through a certain distance, the switch finger flies back rapidly; and in this manner the bad result of a spark is reduced to a minimum and arcing rendered impossible.

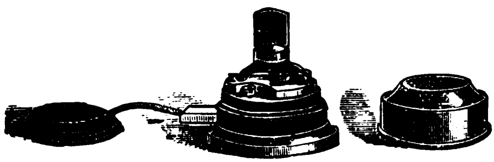


FIG. 38. BROOMHILL COMBINATION SWITCH.

Fig. 40 shows a lamp switch, full size, made by the Acme works. It is very similar to the one illustrated in Fig. 32, but, in some respects, it is an improvement. In Fig. 32, when the finger is on the contact plates, the

spring is kept from forcing it off them by means of a pin, attached to the finger and so placed that the relation between the spring and the pin is at dead point. Consequently, unless everything in the switch is most accurately placed in the course of manufacture, there is a considerable tendency for the finger to fly back of its own accord, when not desired; and in a batch of these switches a few are generally found faulty in this respect.

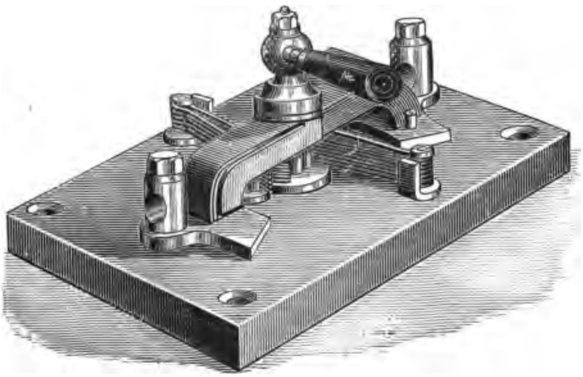


FIG. 39. LARGE SNAP-ACTION SWITCH.

How to remedy this, when it occurs, may be worth knowing. It is only necessary, by means of a pair of pliers, to bend the fixed support of the spring very slightly away from the centre of the switch base, thus weakening the spring to a small extent. In the Acme switch, when turned on, the finger is held in position by a positive lock action: a spring attached to the base of the switch catches a bent-down plate fixed to the spindle

In the drawing the switch is shown locked. On turning the handle the reverse way, another piece of metal fixed to the handle depresses the spring and permits the finger to fly back, this being effected by a spiral spring of hard German silver. In the Woodhouse & Rawson lamp switch the springs are made of steel. They are compound; that is, two or more springs side

FIG. 40. ACME LAMP SWITCH.

by side, so that, in the event of one breaking, the snap action shall not be lost. This firm is now using the circular spring in other forms of switches. The German silver is not liable to break in the same way as steel, so that in the Acme switch the spring is single. In all snap action switches, the handles can be moved at least a quarter of a turn free from the spindle which carries finger.

Fig. 41 illustrates the Drake & Gorham switch, which is very good for large currents, but heavy to work. In this switch a finger passes between the cut made in a suitable compound ring, which has an adjustment to compensate for wear. The stiff working of the switch produces a kind of snap action, because there is a sudden release when the finger passes out of the ring. The muscles of the hand and arm in this case act as if a spring were placed in the switch.

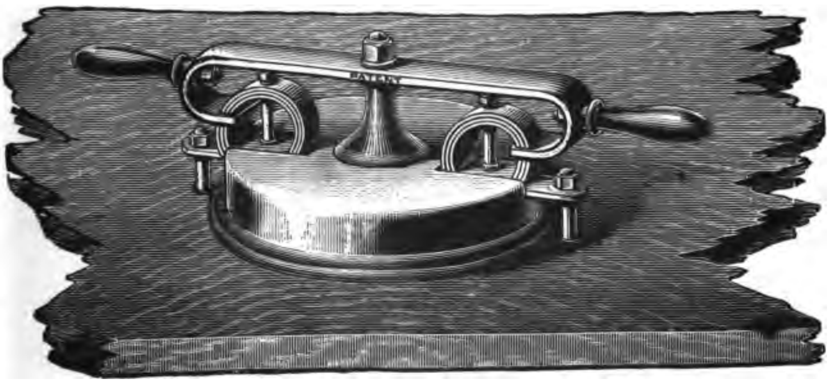


FIG. 41. DRAKE & GORHAM SWITCH.

In Fig. 42 is shown a section of one of the rings (which consists of two concentric rings), with the finger in the slit. When the nuts at the top are tightened the slit in the ring is narrowed.

A double-pole switch, generally termed D. P. switch, cuts both positive and negative leads at the same time. These switches are coming more and more into use, and

for testing purposes they have many advantages. Apart from this, it is often convenient to cut the wires of the residence completely from the source of current. Fig. 31 illustrates Messrs. Woodhouse & Rawson's pattern.

Fig. 43 is the D.P. switch, made by Messrs. Paterson & Cooper.

Fig. 44 is an illustration of the Acme works' D. P. switch.

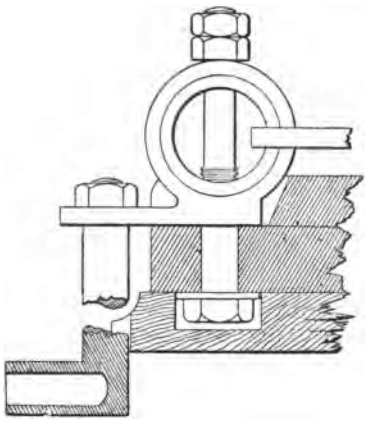


FIG. 42. DRAKE & GORHAM CONTACT RING.

Other good forms of switches exist, made by many good firms, such as Messrs. Crompton, the E. P. S. Company, and the Globe Electrical Company. Nor must the "Pointsman" switch, by Messrs. Farraday, be passed unnoticed. It may be mentioned that the arched form of compound switch finger, now being adopted almost universally, was first devised by the author, and is not

patented. The switch made by Messrs. Siemens also deserves special mention, for it is probably the only good one made for breaking large currents. Its principle is that the last break is taken off carbon points, so that no metal is burnt; and when the carbon rods, which may last for years, are consumed, they can be renewed in a

FIG. 43. PATERSON & COOPER'S DOUBLE POLE SWITCH.

moment at the cost of a half-penny. The switch acts thus: the metal parts are of the usual form, but in addition it has two arms, one fixed and one movable, each carrying a short rod of carbon, through which carbons the current still passes when the finger has moved off the contact piece, the rods being kept together by a spring or cam. On moving

the switch-handle still farther, they separate, and if a current is flowing, the circuit is broken with the usual spark. When closing, the carbon rods come first in contact, then the metallic parts.

There is really no spark on making contact with low E.M.F.; it is on breaking the circuit that the spark is formed, and this may be regarded as the momentum of the current continuing to flow during the cutting action. Messrs. Siemens are now making various switches on this pattern, with a snap action.

FIG. 44. ACME D. P. SWITCH, SNAP ACTION.

Many other switches have been devised to avoid heavy sparking, such as the "many-break" switch, where the spark is divided into a number of small ones; also a step switch, with a resistance between each step, reducing the current gradually, so that the total spark is divided over all the steps. Still, none are so good as the "carbon last break" of Siemens; and it appears remarkable that these are not more in use.

There is a possibility that some day a true sparkless switch may be made; its action must depend on setting

up, momentarily, a counter E.M.F. equal to the E.M.F. of the current to be broken. In such a case no spark would be produced. The result could be effected by the introduction of an induction coil, constructed in a manner suited for the end desired, or by means of a voltameter.

Already a sparkless switch can be made for use, with alternating current; but, as this book does not make a point of dealing with this kind of currents, a mere statement of the fact will suffice.

It is of great importance that the snap action in a lamp switch should be very perfect and certain, so that by no possibility can it be left half on, or in an arcing condition, *i.e.*, so that the spark, created on cutting, shall continue. The arc is broken if the finger moves through a sufficient distance. This result is brought about by the snap action, or its equivalent, and the possibility of fire is guarded against.

The bases and covers of all switches are best made of incombustible material, and fixed in a safe place. It is rare that harm is done, even if the switch be left arcing, for the metal burns away, and eventually the arc is cut by increasing its length; yet it is advisable to guard against this. The lamp will indicate whether an arc exists at the switch, for it will glow but very dull, as if turned down. But it must not be supposed that the simple fact of burning dull necessarily indicates an arc, for this might be produced by other causes.

There is no simple way of turning down a lamp although for this purpose switches, containing carbon, resistances, and other devices have been made. They

have not come into use, because the power absorbed by a lamp turned low is practically the same as when bright. Therefore, no economy worth mentioning is produced; and the lamps are so easy to relight that it is better to turn them off altogether. Compared with a large one, a small lamp is an economy; but in both cases the actual brightness of the filament is the same. Consequently, when full and half-light are required, two lamps should be used, one or both being turned on at pleasure. It is true that a lamp burning low takes less current, but the resistance used to effect this end consumes power. The majority of lamp switches turn on like a gas-tap; others pull out like a bell-pull to turn on, and push in to extinguish the light.

The Edison-Swan switch has a tumbler action. Others have levers. In fact, almost every day some new pattern of switch is brought into the market. The acorn-shaped switches of Messrs. Lang, Wharton, & Down are very convenient for attaching to flexible cord for the bedside. The Browett pull switch is fixed near the cornice. By pulling a cord, the light is put on; and with another pull it is turned off. It is convenient for a night switch. With this switch, the wires need not be brought down the wall; which is sometimes an advantage. By proper arrangement, the switch may also be worked at a distance. Some like switches to "snap on" also.

The author has brought out two kinds of switches, one very similar to the Browett, but smoother in action. Its manufacture being more expensive, it was not found worth while to make it on a large scale. The other is

shown in Fig. 38. It is an ordinary switch with an addition to its base, by means of which a portable lamp may be attached, the connecting plug of the lamp, after insertion, being used as a key for switching the light on and off. It will, therefore, be observed that this is equivalent to a combination of two switches and a wall-connector; and the arrangement is such that only one fuse is required to both. By means of these switches, portable lamps may be used throughout the house, having independent switches in every case. The figure represents the switch with the cover off, and the connector inserted. The coil of flexible wire at the side is intended to be attached to a portable lamp. It is now in the hands of Messrs. Woodhouse & Rawson for manufacture. The plug switch can be made snap action.

There are also magnetic long-distance switches, which at times are found convenient. Wall-connectors are most useful about a house for attaching a portable lamp, or small motor, at will.

Although there are numerous makers of wall-connectors at the present time, all the best are practically built up on one plan; and the credit for the original design is due to Mr. Taylor Smith.

The author has recently devised a form of wall-connector, which he believes to be a great step in advance. The outer case is of solid metal, and the incombustible base, which carries the electrical portions, is so arranged as to be free within the casting. When this connector is used as a ceiling plate, or for a standard,

the weight of any fitting is completely carried by the metal portions; so that no strain is placed upon the slate or porcelain. It is taken apart by unscrewing the cover, which has a flange that covers the screws fixing the whole apparatus to the wall, floor, ceiling, or table. The back of the metal base plate has a ring of vulcanite attached to avoid the possibility of creating a short circuit, if the wires pass too close to the metal. Before the metal cover is screwed over the base plate, a slate or porcelain loose cap is put over the electrical portions, so that these are entirely encased by non-conducting and incombustible material. It contains a fuse one inch long, in accordance with fire-risk regulations. The front end of the metal cover has a thread around it to receive an ornamental ring. This ring is made in a number of ways according to the purpose for which the connector is to be used. When employed as a ceiling or bracket plate, the connector-plug is covered by a cap so made that the ring holds it firmly in position, thus preventing the possibility of the plug being drawn out by the weight of the lamp fitting. This method also applies when the connector is used as a standard fixed on a table, desk, or the floor, unless it be desired to have the fitting removable without the necessity of unscrewing the ring. The plug-connector also has an improvement in it, instead of having to fix the wires, as hitherto has been the case, inside the cap, which is a very inconvenient proceeding, the cap is removable, and the plug-pins being attached to a flat disc which screws into the cap like the lid of a box, and permits of the attachments

being made with perfect freedom. Messrs. Faraday have taken this switch in hand. A fuse can be put in the cap if desired, which is often found convenient for renewals without turning off the current.

Fig. 45 illustrates an ordinary form of wall connector with the plug in place.

Fig. 46 is a similar apparatus in porcelain, with the plug removed to show the two connecting pins.

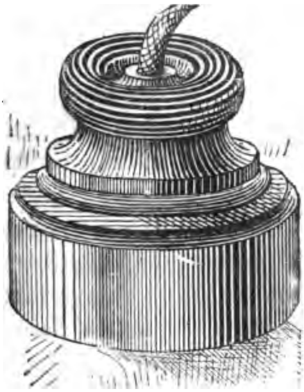


FIG. 45. WALL CONNECTOR AND PLUG IN.

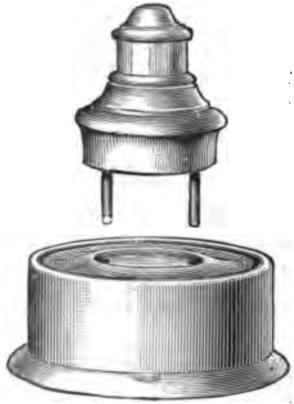


FIG. 46. WALL CONNECTOR AND PLUG OUT.

Apart from the electrical and mechanical requirements already pointed out, which are demanded for lamp switches and wall-connectors, the following should also have attention. All the electrical portions should be so arranged as to be covered, and such coverings perfectly insulated, so that no person in handling a switch or connector can possibly place himself in electrical communication with the conductors, whereby he might,

under certain conditions generally existing, receive a shock which might be very dangerous if high E.M.F. were employed.

It is possible to render wood fireproof, by impregnating it with tungstate of soda; and, when this is done, it may be used to replace slate or porcelain, but the latter are to be preferred. Many kinds of earthenware and artificial stone have been produced with a view of obtaining the advantages which slate gives without its defects. Serpentine has also been much used. Ebonite, though a first-class non-conductor, is injured by heat, and, therefore, not very suitable for switch and cut-out bases. This material also becomes moist on its surface by the sulphuric acid, which separates from its substance, producing surface conduction and injuring any metal which may be attached to it. Notwithstanding these drawbacks, the use of ebonite is found to be an advantage in very damp situations; and it is necessary that all metal portions mounted on them should be large enough so as not to heat. Vulcanite fibre is not much inferior to ebonite, but is unsuitable for damp situations; for the leakage produced by moisture tends to carbonise the surface due to the presence of salts in the substance, and thereby impairing its good insulating properties. Professor Vernon Boys has recently discovered that quartz is a remarkable insulator, even when the surface is moist. This substance is costly to work, but in some cases, where great difficulty exists in preventing leakage, it may, notwithstanding the expense, find employment.

In the house there can be no doubt that the best

place to put the lamp switches, with their fuses, is upon the shutting doorpost or the wall close by. In this manner a room may be lighted before entering, the door having first been opened to obtain access to the switch. By working upon a symmetrical plan the switch can be found in any room throughout the house; in the same way, in passages, some system of placing the switches should be followed. When "tap" switches are used, the tap vertically placed should be "on," and horizontally "off"; this avoids doubt as to whether the circuit is cut or not in the case of worn-out lamps, broken circuits, and the like. These points settled, attention should be given to the matter of wall connectors for portable or fixed lamps, which should be placed near all tables generally used for work, and by bedsides, where the switches may, with advantage, be painted with luminous paint. Many rules have been laid down as to the number of lamps required to light a room, but they have no practical value on account of different decorations absorbing more or less light; and when there are pictures, considerably more light is required. The quantity of light also depends a good deal on the fancy of the individual. Much depends on the positions of the lamps and the levels on which they are placed. The best and most reliable way is to take a number of good light-giving lamps, such as the kerosene duplex, which gives about the same quantity of light as a 16 c. p. incandescent lamp, and to place them about the room, high and low, till the desired effect is

obtained. This test serves as a guide for the wiring, and fixes the positions where lamps shall be put. The most pleasant lighting is obtained by placing the lamps round the room about eighteen inches or two feet from the wall, and seven to eight feet from the floor. This method is the most economical; and in rooms to work and read in a few more lamps may be placed so as to obtain additional light at special spots. When a room is only used for reception purposes, a better effect may be produced by placing the lamps ten feet from the floor. Fittings are better dispensed with, the lamps being simply suspended, from the ceiling or from brackets, by flexible twin wire, and when desired they can be obtained ground or obscured to avoid glare, or they may be toned down with silk shades. Ground or obscured lamps waste 15 or 20 per cent. of light, but it does not follow that this is a disadvantage or even waste in all cases, for the obscured globes diffuse the light much more equally.

All incandescent lamps, giving the same light, absorb practically the same power. For instance, a 100 volt 16 c. p. glow lamp requires 0·6 ampère, or expressed in power by watts, $0{\cdot}6 \times 100 = 60$ watts. If it is desired to find what current is required by a 50 volt 16 c. p. lamp, proceed thus:

$\frac{60 \text{ (watts)}}{50 \text{ (volts)}} = 1{\cdot}2$ ampère. To obtain 32 c. p., 210 watts are necessary, and so on, the number of watts consumed in glow lamps being nearly proportional to

the light as they are now made. It has already been stated that 746 watts = 1 E.H.P. = 1 H.P. = 33,000 minute foot pounds. Since 746 ÷ 60 = 12·43, implying that theoretically 1 I.H.P. in the engine

FIG. 47. COVER OF PENDANT SOCKET HOLDER.

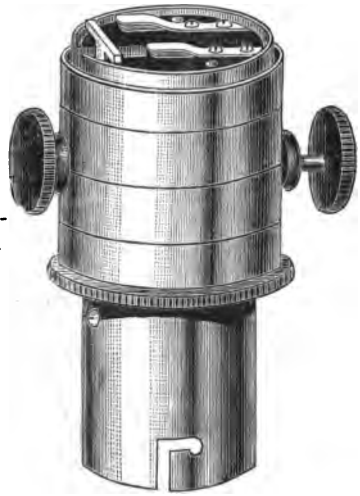


FIG. 48. PENDANT SOCKET HOLDER, WITH SWITCH SELF-CONTAINED, COVER REMOVED.

should light between twelve and thirteen 16 c. p. lamps. Evidently this number cannot be obtained in practice, since there must be a considerable loss

of energy in the production of the current. In practice, under the best conditions, as many as ten 16 c. p. lamps can be lit to 1 I.H.P. of the engine, so that it may be roughly said that the commercial efficiency is about 82 per cent.

The vitrite holder, and those built up after its type, still maintain the first position amongst its army of competitors.

FIG. 49. SWAN SOCKET LAMP.

Figs. 47 and 48 show a socket holder and switch combined, suitable for suspension. The top (Fig. 47) is shown removed, in order that the switch action may be seen. Pushing one knob or the other lights or extinguishes the lamp.

In residences the socket lamps (one is shown in Fig. 49) which fit these holders are by far the best to employ, since any ordinary domestic can replace

a lamp with the greatest facility. It is necessary to observe that the spring contacts in this class of holder are of sufficient length and strength to ensure a perfect contact when the lamp is inserted. Otherwise, considerable heating will take place, which may lead to the destruction of the lamp and holder. If this attention has been given in the first instance, no further care is required.

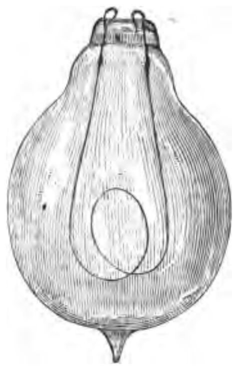


FIG. 50. SWAN LOOP LAMP.

Loop-lamps (one is illustrated in Fig. 50) are probably the best to use in places subjected to considerable vibration, and in the open air, since the contacts are more certain and firmer in the first case, and, practically, there is no metal to corrode in the second. But more care is needed in attaching these lamps.

Loop-lamp holders are shown in Figs. 51 and 52, the first being suitable for fittings and the second for

suspension. In Fig. 52 the cord is gripped, so that the usual knot is avoided.

Arc lamps scarcely come within the province of private house lighting, but a word or two on this subject may be useful. Siemens, Crompton, Brockie-Pell, and many other lamps rank as first-class, the

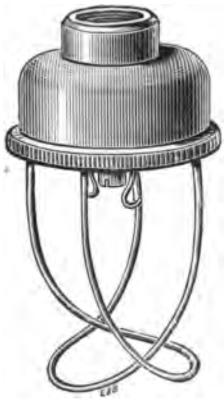


FIG. 51. FITTING LOOP LAMP HOLDER.

FIG. 52. PENDANT LOOP LAMP HOLDER.

last named being, perhaps, the most perfect of all. Woodhouse & Rawson make a lamp, an excellent one, for small currents, and it is extremely steady. In all cases the pressure required for each lamp varies from 40 to 55 volts, or 60 to 65 volts in very large lamps, and the light is in this case

produced not by an incandescent filament lasting some 2,000 hours, but from two carbon rods placed in holders, their free ends, not in contact, being maintained at a high temperature by the passage of the current, which jumps this interval. In small lamps, the space between the two carbon rods is 1-16th inch, and in large 1-4th of an inch, the passage of the current being indicated by a curved flame or "arc," but the light is produced by the incandescence of the carbons at the point of separation.

FIG. 53. ELECTRIC ARC.

The positive carbon burns hollow or cup shape, and transfers carbon to the negative rod, which becomes pointed.

An arc lamp placed overhead should have the positive carbon uppermost, assuming that the carbons are vertical, so that the light is sent downwards from its incandescent cup. If this order is reversed, the bulk of the light will be sent upwards towards the ceiling or the sky. In rooms, therefore, where reflected light may be more desirable than too much direct light, the positive carbon may be lowermost with advantage. It is thus seen that the positive carbon must face the direction in which the light is

to be thrown. In order that the automatic feed of the carbons may be properly regulated, so that the length of the arc may be maintained constant, the adjustment screws for this purpose, which are attached to the mechanism of the lamp, must be attended to. The chief reasons why arc lamps so often flicker are because the feed is irregular and the carbon impure or contains air cavities.

In air the positive carbon burns twice as fast as the negative. The arc flame is not visible electricity passing, but simply heated gases. Arc lamps require much attention, for it is necessary to clean and trim them with new carbons daily. As a rule the lengths of carbons employed last from six to eight hours, and in many instances the lamps hold two sets of carbons, the second set striking an arc automatically when the first has burned out ; in which case they will produce light for double the time.

Some protection is necessary against fire from falling pieces of incandescent carbon, also against wind, which might blow out the arc.

Globes and lanterns should always be protected by wire netting to prevent accident, in the event of their breaking from any cause.

An increased current greatly increases the light, the proportion of current to light not being direct as in the case of glow lamps.

Alternating current arc lamps make a buzzing noise and work at an E.M.F. of 35 to 40 volts. No crater is formed, and both carbons consume at equal rates.

A diagram of a 2,000 c. p arc is shown in Fig. 53, with the positive carbon uppermost, from a photograph taken by the author by means of two Nicholl's prisms at a distance of 16 inches from the arc.

Many persons imagine that the electric light gives no heat, and are much puzzled when told that the electric arc is the highest temperature known at the present day. It is perfectly true that the arc light is cool for illuminating purposes, for the actual mass raised to so high a temperature is extremely small for the enormous amount of light given out. It must also be borne in mind that arc lamps give off noxious nitrogenous fumes which are very noticeable in confined situations. Glow lamps emit absolutely no fumes, since they are hermetically sealed in glass globes. On the other hand, they produce a considerable quantity of heat, but far less than gas or lamps, light for light; and, difficult as it may be to believe, wax candles give more heat, light for light, than either of the latter-named illuminants.

The "Electrician" of June 14, 1889, gives a paragraph from an interesting letter written by the late Sir C. W. Siemens, in respect to the comparison between the light-giving power of arc lamps and gas :—"A very powerful arc light gives as much as 33 per cent. of the energy absorbed in the arc as luminous rays (25 per cent. measured horizontally), whereas Tyndal found a vivid gas-flame to yield $\frac{1}{25}$th of its radiant energy as luminous. But the $\frac{24}{25}$th is the loss only by invisible rays, and does not include the heat carried up through the chimney as heated air, which loss is not an invariable

quantity, but amounts to at least four times the radiant heat. This makes the total heat developed in combustion of the gas $25 \times 4 = 100$ times greater than that sent out in the form of luminous rays."

We may now turn to the fittings. These may be selected according to the taste of the owner; but the general mistake of trying to make the electric light appear like gas should be avoided. Gas must have a pipe, and in order to hide its ugliness ornamentation becomes almost a necessity, especially when the pipe is long or crooked. Again, gas jets at many points means complicating the piping in the walls, and to avoid this groups of lights are resorted to. Electricity being free from all such drawbacks, there is no need to group the lamps, which is a bad and wasteful mode of lighting; nor is there any difficulty in putting them in any part of the room, although decorated and furnished; in short, the more conspicuous the absence of fittings and groupings, the greater the charm of the light and the more magical its appearance.

As to portable fittings, there have never been any to excel the designs of Mr. Taylor Smith for beauty, lightness and practical service. A new fitting has recently been devised by the author, and is shown in Fig. 54, manufactured by Messrs. Faraday. It meets a particular want, which the author found had not been supplied. It is simplicity itself, as it permits a lamp to be fixed in a shade, which can be adjusted at all angles, and may be pulled up and down at pleasure, merely by placing the shade as required; and there it remains. Each

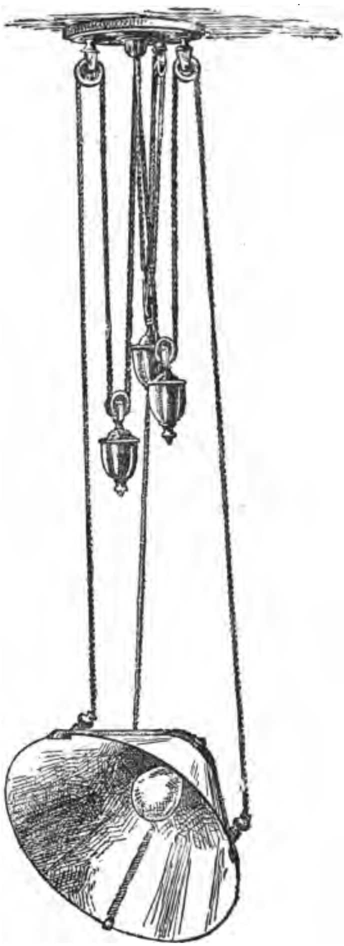


FIG. 54. SIR D. SALOMONS' PERFECT CANTING PENDANT.

lamp so fitted avoids the necessity of two or three lights for writing tables, work benches, and so forth. The eyes also are shaded, when desired. This lamp has been called the " Perfect."

These pendants are now made in far more ornamental and graceful forms than that seen in the illustration. For picture reflectors the shade is replaced by gilt shell, silvered inside ; and the method of suspension lends itself most conveniently to that purpose. Miniature ones are also made for the toilet table. Reflectors for photographing by electric light are generally suspended on this principle. The ceiling plate is now replaced by the author's design of wall connector, which has been called " The Universal," a ring being added with three spokes, which bear the pulleys.

All suspensions and fittings should be easy of removal in case of repairs or when a room has to be re-decorated. Glow lamps may be placed close to tapestry, ceilings, or inflammable substances, provided they are not in absolute contact, which would produce a slight charring or discoloration. Even if the glass globe breaks, there is no danger from fire, because the heated carbon filament, in the presence of the oxygen of the air, becomes immediately converted into carbonic acid gas ; *i.e.*, on breakage occurring, the light is extinguished by the instant destruction of the filament. It must not be supposed from this remark that the whole filament necessarily dissappears. If any part of the filament is weaker than the rest, it will naturally go first, and the circuit will be cut, so that any portion

of the filament remaining will no longer be acted upon by the oxygen, since it has lost its high temperature.

No part of a fitting should be used in place of a return wire. All wires passing into and through fittings should be well insulated. The fittings cannot be too well constructed, since they should last many life-

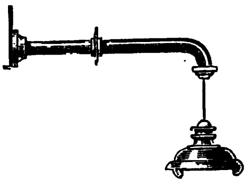


FIG. 55. PENDANT BRACKET.

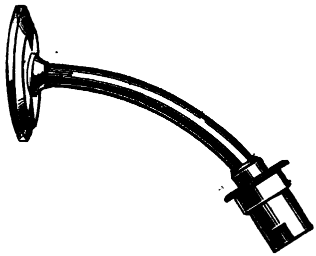


FIG. 56. WALL BRACKET.

times, and will probably be handled pretty frequently for the renewal of lamps. It is not, however, necessary that they should be heavily or clumsily made. The illustrations shown of a few fittings will give some idea

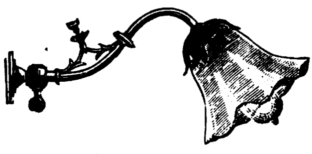


FIG. 57. ORNAMENTAL BRACKET.

of their appearance and principle, but they are not given to indicate any special taste.

Fig. 55 is a bracket, carrying a shade-holder suspended from it by means of a flexible twin cord.

Fig. 56 is a plain bracket, with a vitrite holder attached.

Fig. 57 is a more ornamental bracket, with a bell-shade.

Mr. Taylor Smith's pattern of portable lamp has a reel of twin wire in its base, with the ends of the wires going to the lamp-holder and a connector plug respec-

FIG. 58. PORTABLE TABLE LAMP.

tively. The two pins of this plug are pushed into the wall connector in the usual way to obtain the light. The lamp, when so attached, may be carried to any part of the room, as the wire unwinds from the reel, and this can be rewound by means of a handle situated under the base.

Fig. 58 shows one form of portable table-lamp.

Fig. 59 illustrates a protected portable lamp, suitable for a workshop or cellar.

However good the insulation of the conductors of the circuit may be, as soon as the switches and fittings are added it is found that the insulation falls considerably. In new buildings and in damp places much difficulty is often experienced. To surmount these troubles the following precautions are essential. All fittings,

FIG. 59. PORTABLE CELLAR LAMP.

whether switches, ceiling, wall-plates, or otherwise, should have placed behind them dry wooden blocks shellac-varnished, or plates of ebonite ; and the screws which pass through a fitting, to connect it to the wall or ceiling, should be perfectly insulated from the electrical circuit.

It is desirable to put a safety-fuse in every switch

and wall-plug ; and should this, from any reason, not be convenient, the fuse should be independently placed close by.

There is then no difficulty, when a fuse melts, in finding the point. Each lamp, as well as each room, is protected in this way against accidental short circuits.

As the meaning of a short circuit is not clear to everybody, an example may be given to explain its importance and danger. Take the case of a 100-volt current, supplying a 16 c. p. lamp which takes 0·6 ampère, and let the leads to the lamp have a resistance of 1 ohm (ohm is the standard unit of resistance). Now such a lamp has a filament with a resistance of 170 ohms approximately, so that when lighted the passage of the current is opposed by 171 ohms, and this obstructive resistance allows only 0·6 ampère to pass. It is clear that, if the two wires leading to the lamp touch at any point so as to permit the current to pass from one wire to the other before it reaches the lamp, the latter is cut out of the circuit, and 170 ohms are removed, for the current will take the course of least resistance ; therefore 170 times more current would flow, burning up the wires, since they are not large enough for such a heavy current, doing great mischief to the cells, and possibly to the dynamo, if specific precautions are not taken. These safeguards consist in cut-outs, which break the circuit the moment the current exceeds a certain value. Every branch from the mains and secondary mains and every twin wire should have a safeguard, and in private houses the mains should possess them as well. It is advisable

to place all cut-outs, often called safety junctions, within easy reach, and to so construct them that the circuit can easily be re-established by resetting or inserting a new fuse without recourse to tools.

Cut-outs are of two kinds—one is magnetic, and the other depends on temperature. The mains and branches are always laid to carry safely for any period at least twice the current required, and, under these conditions, ten times the maximum current of the installation may be passed for a short period without risk. Hence there is no necessity for these safety devices to cut the circuit for any special current, so long as the setting is kept well within allowable margins ; for instance, say, three times the current intended to be used for that particular main or branch.

Fusible junctions are most commonly used. They consist of tin-foil or wire, which melt on too much current passing, the section of the material being adjusted to the requirements of the circuit. Mr. Alexander Siemens has shown that no danger to insulation occurs until a temperature of 150° C. is reached ; also that no fusible junction should be employed which will melt till three times the current is passed which it has to guard. If the fuse goes at a less margin, it gradually oxidises ; and, eventually, the circuit is cut when not intended, and great inconvenience may result. We see that the 200 per cent. margin provides really more than ample safety.

Mr. Preece advocates the use of platinum wire for fuses, as this metal does not oxidise in the air. He has

shown that, for any current which renders a platinum wire red hot, double that current makes it white hot, and three times the current which makes it red, fuses it. This is interesting from a scientific point of view, but the possibility of having a number of white hot fuses about a house is not to be courted.

On the other hand, Mr. Cockburn recommends a fuse wire of tin, loaded in the centre with a piece of lead, which breaks the wire by its weight as soon as the plastic stage is reached, whereby the wire never reaches red heat temperature. This fuse appears to offer every

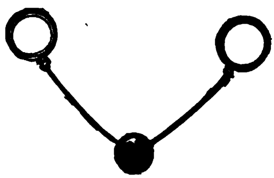


FIG. 60. COCKBURN FUSE.

advantage, for, apart from the one already stated, there is no splash of liquid metal on the fuse breaking, nor any blackening of the terminals. This fuse can be made to go with great precision for a particular current by suitably adjusting the weight of the load.

Fig. 60 shows a Cockburn fuse with a drilled shot on the tin wire.

Fig. 61 illustrates two Cockburn fuses in position, one on each main.

Fig. 62 is a compound Cockburn fuse for a large current, four fuses being placed in parallel. It will be

noticed that each fuse carries a larger weight than in the other ones shown, because the wire, being larger in this instance, requires a heavy weight to break it.

In no case should the fuse wire be too short; it must at the least be one inch long, and its length should be increased in proportion as the terminals, to which it is attached, are larger, since large masses of metal conduct the heat away from the fuse very rapidly.

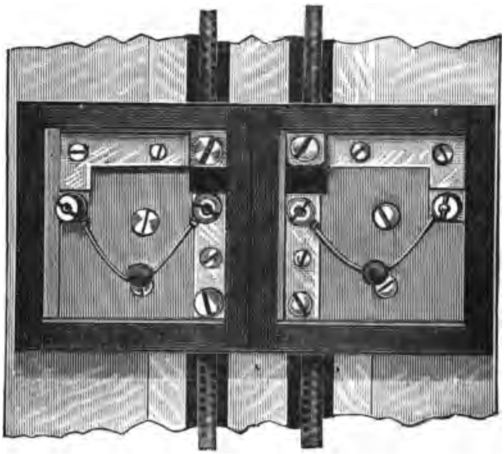


FIG. 61. D. P. COCKBURN FUSE.

Fig. 63 is a Woodhouse & Rawson pattern of cut-out, very similar to that adopted by most other manufacturers. The fuse itself consists of tin-foil cemented to a piece of vulcanite fibre. The ends are slotted, in order that it may be pushed under the terminals without the necessity of completely removing the screws. Mr. Killingworth Hedge's fuses are also

tin-foil, placed between pieces of mica for mechanical strength.

Fig. 64 shows a double-pole fuse, consisting of a porcelain block with two channels, in each of which is situated the usual terminals and a fuse wire, the whole being covered by a piece of glass.

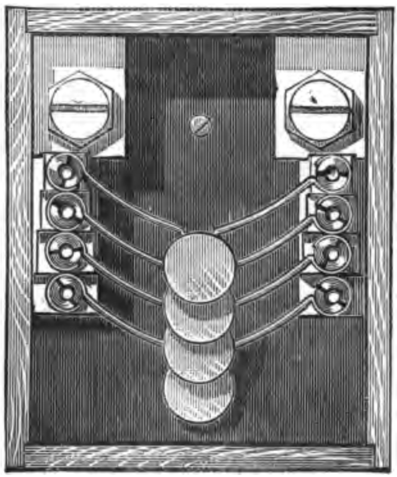


FIG. 62. COMPOUND COCKBURN FUSE.

The author's experience is, that for fusible cut-outs, ordinary tin-wire answers quite as well as any of the numerous types of fuses which have been brought into the market; and, combined with Cockburn's improvements, there is nothing more to be desired.

From the remarks already made it is evident that to

have a fuse so accurately adjusted as to protect a lamp, is likely to cause its extinction at almost any moment, since the margin allowable is so very small. It is unquestionably better to rely upon the good design and workmanship of the installation for the protection of the lamps than upon devices which are intended to come into operation only in cases of carelessness and accident. If cut-outs are used with this view only, the security sought is completely obtained.

FIG. 63. TINFOIL FUSE.

Besides the fuses just described, many other designs have been brought out for cutting the circuit, depending upon a rise in temperature, such as the well-known cut-out, consisting of two different metals soldered together, and working by expansion and contraction; also another made with mercury. But these need not now be discussed, for common fuses acting by fusion are far simpler in construction and more reliable. Magnetic cut-outs are, however, an exception; and a large variety of these exists. They can be arranged to go off

for a definite current. Cunynghame's magnetic tumbler cut-out is by far the best of all present patterns. A diagram of this is shown in Fig. 65. The current passes through mercury, but this is not an objection. When the current becomes too large, the magnet draws up the armature, with the arms which dip in the mercury cups, to which they are attached ; and the circuit is cut, not to be re-established except by hand, since the momentum given to the moving armature causes it to pass over the magnet and to fall against a pin on the opposite side to that where

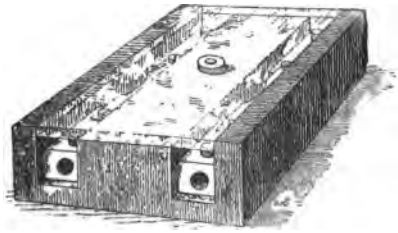


FIG. 64. D. P. FUSE.

the mercury cups are, and the magnet loses its power the moment the arms are withdrawn from the mercury, since its exciting power is obtained from the main circuit, for the insulated copper ribbon wound around its core forms an integral portion of the main, which passes to one mercury cup and continues from the other, the break being bridged electrically by means of the arms, when they rest in the cups. These devices are extremely useful where cut-outs are often likely to go, such as those employed with motors, in the engine-house, and for experimental work, since they can be reset at once ;

for a fuse takes longer time, and is more troublesome to replace. For use on board ship the instrument is somewhat modified in construction. Magnetic cut-outs are not suitable, as now constructed, for alternating currents.

The best method is to duplicate cut-outs for currents over 10 ampères by using a fuse against all chances, and

FIG. 65. CUNYNGHAME'S MAGNETIC CUT-OUT.

a magnetic cut-out set for a less current than the fuse. These act as checks one on the other, and permit of easy resetting at any time, as the magnetic cut-out goes first. All fuses should have incombustible bases and covers.

The only instruments required in an installation

are the ammeter and voltmeter. In most instances both are made in the same way, the difference being simply in the resistance of the wire upon the instruments. The ammeter gives an indication of the quantity of current flowing through it without sensibly lowering the E.M.F. The resistance of an ammeter must be very low, so that the loss of pressure in passing through the instrument may be reduced to a minimum. Otherwise, there would be a considerable amount of power wasted. In the voltmeter it is the reverse. Its resistance must be very high so as to allow only a very small quantity of current to pass. The indications will be proportional to the quantity of current passing and, therefore, to the pressure forcing it through. This instrument is connected not in the course of the leads as with the ammeter, but across them, like a lamp placed in parallel.

The majority of these instruments may be divided under four heads:—

1. Direct reading.
2. The instrument must be set for each reading.
3. Direct reading, and result obtained by calculation.
4. Set for each reading, and result by calculation.

Then, again, all these may be divided into instruments that are dead beat and those that are not. When calculations are necessary, for convenience, a table of reference is generally used.

The dead beat direct reading instruments are the most convenient, because the needle comes to rest at

once, giving the correct reading on the scale, in ampères or volts, but, as they are liable to alter, they require periodical recalibration. Some instruments must be observed far removed from currents and masses of iron. Each kind has its uses, and to obtain accuracy several patterns should be employed for checking one another, if no standard exists.

Illustrations are here given of a few of the leading ammeters and voltmeters.

FIG. 66. JOEL & PATERSON AMMETER.

Fig. 66 represents a Joel & Paterson's pattern engine-house ammeter, giving approximately correct indications. It reads direct, but it is not dead beat. Large currents flowing near this instrument affect the readings. Its action depends, simply, on the current to be measured passing through a strip of copper

before which a permanent magnet, attached to a pivoted spindle, swings vertically. The needle is kept upright when at rest by a weight attached to an arm fixed to the spindle; and this spindle carries a long light pointer, which reads upon the scale. Adjustment is obtained by increasing or diminishing the distance of the weight from the spindle. It is evident, therefore, that the principle of this ammeter depends upon the displacement of a swinging magnet

FIG. 67. DEAD BEAT AMMETER (SIMPLE.)

against gravity, recalibration at times being necessary in consequence of the changes which may take place in the strength of the permanent magnet. This is, perhaps, the simplest possible form of ammeter.

Fig. 67 shows an ammeter by Paterson & Cooper, and common to other makers, which works by means of a coil of wire, in the centre of which swings a permanent magnet, carried upon a pivoted arbor. Around the whole is placed a horse-shoe

permanent magnet, and between the poles of the latter the pivoted magnet swings. The spindle carries a pointer, as in the last case. This instrument is dead beat, because the magnet moves in a strong magnetic field. It is also direct reading and fairly reliable. Recalibration must occasionally be resorted to. The usual adjustments are found upon the instrument.

FIG. 68. DEAD BEAT AMMETER (COMMUTATOR.)

Fig. 68 is an improved form of the preceding pattern. The coil is, in this case, subdivided into ten coils; and these can be placed in parallel or in series by means of the commutator seen in the plate. When the coils are in parallel each degree has ten times the value they have when in series. Formerly, this instrument had a piece of iron placed against the poles of the permanent magnet for an armature, the idea being that by so doing the strength of the horse-shoe

magnet would be more constant over a long period of time. Experience has proved this to be an error. Alterations in magnetism were soon produced by continually plucking off and replacing this armature, and Sir Wm. Thomson has shown that a well "aged" piece of steel, when magnetised, will keep its magnetism nearly constant for a very long period. The expression "aged" is used to imply that the metal has been subjected to considerable rough usage, such as successive heatings and coolings, hammering, and the like. This form of ammeter was originally devised by Messrs. Ayrton & Perry. It will be noticed that there are three terminals shown upon the instrument, one marked P, one S, one P S. For small indications of current terminals S and P S are used, and coil placed in series, otherwise no current passes. For large indications P and P S are employed, and coils in parallel; P S therefore is a common terminal, P takes a large wire, and S is only capable of taking a small one. By this arrangement the passing of a large current through the instrument when the coils are in series, and thereby destroying it, is rendered an impossibility. The plug, seen in the drawing, is used for calibrating the instrument, and is in connection with a 1 ohm coil.

The following is the method of calibrating:—

In both simple and commutator instruments the adjustment by which the deflections are rendered direct is made by moving the galvanometric coil from a stronger part of the field into a weaker part,

or *vice versâ.* The coil is supported by two screws, and by means of nuts it can be moved as above described. On unscrewing the base board the magnet and coil of the instrument are exposed, and the adjustment can then be made.

To calibrate the Commutator Ammeter turn the commutator to series, and send a current from a standard cell of known E. M. F. through the ammeter, obtaining a deflection D. Pull out the 1 ohm plug, the deflection will now be reduced to d. If E is the E. M. F. of the cell in volts, then current $= E \frac{D - d}{d}$ for deflection D, and 1° gives $E \frac{D - d}{D\ d}$ ampères in series, or 10 $E \frac{D - d}{D\ d}$ ampères in parallel. The adjustment of the coil must be made until the desired value per degree is obtained.

To calibrate the Simple Ammeter, place it in series with a standard instrument having about the same range, and let the current flow through both, adjusting the coil of the former until the desired value per degree is obtained.

Crompton & Kapp's instruments are very good. They are direct reading, but not dead beat, and must not be placed near currents or masses of iron. At first a difficulty was experienced by residual magnetism, but this defect has now been almost cured. In these instruments, the magnetic field is produced by the current to be measured. It is said that if a

needle of soft iron replaces the swinging permanent magnet, the instrument may be employed to measure alternating currents.

Fig. 69 illustrates an ammeter devised by Mr. Hubert Davies, and manufactured by Messrs. Woodhouse & Rawson. The arrangements in this instrument are such that currents flowing in its proximity do not affect the readings. It indicates in ampères direct, and

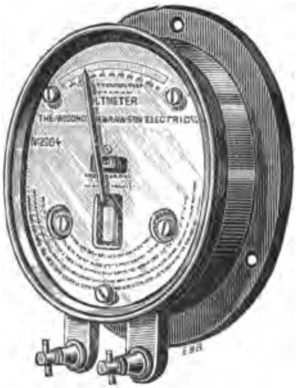


FIG. 69. DAVIES AMMETER.

is fairly dead beat. As in the majority of ammeters, the direction of the current is shown by means of a small supplementary pivoted permanent magnet.

Fig. 70 shows a Drake & Gorham ammeter. Its principle depends upon the strength of an electro-magnet varying with the current which passes around it, this current being the one to be measured. In front of one pole of the magnet is pivoted, a little eccentrically, a disc of iron which carries the pointer.

This disc has small shifting weights upon it for making adjustments. It is evident that, if the disc be rotated, the distance between its periphery and the pole of the magnet will continually alter. In action the disc rotates and diminishes the distance as the magnet becomes stronger; and in this manner

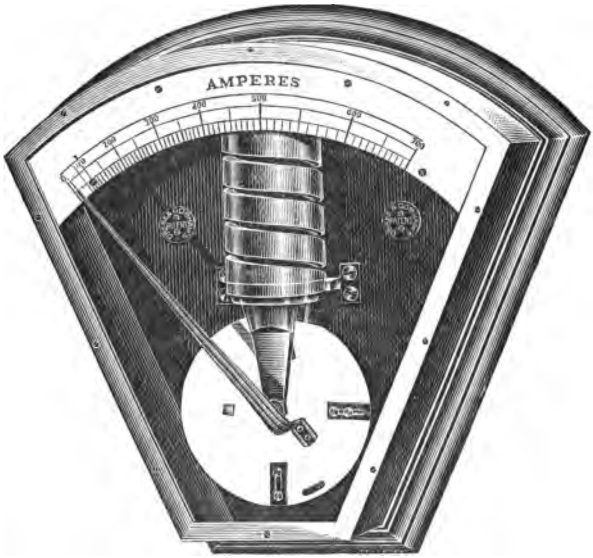


FIG. 70. DRAKE & GORHAM AMMETER.

the needle is made to read upon the scale. The instrument is direct reading, and almost dead beat.

Fig. 71 shows Ayrton & Perry's long range ammeter, the makers being Messrs. Latimer Clark and the Acme Electrical Works. In this a small piece of iron is sucked into a solenoid against a special form of spring, more or

less as the current is stronger or weaker. The spring consists of a spiral ribbon of phosphor bronze coiled edgewise, and this at one end carries a needle which passes

FIG. 71. AYRTON & PERRY'S MAGNIFYING SPRING AMMETER.

over a dial. For any extension of such a form of spring, a large rotary movement is given to any point upon it. In the base a compass needle is shown, which is employed to indicate the direction of the

current. This instrument is not dead beat, but is direct reading, and requires occasional recalibration.

Figs. 72 and 73 illustrate Siemens' dynamometer. Fig. 72 is the common form, and Fig. 73 the better class of instrument; but the details are the same in both. Here the current to be measured passes successively through a fixed coil and a

FIG. 72.
SIEMENS' DYNAMOMETER.

FIG. 73. SIEMENS'
DYNAMOMETER (BEST FORM).

movable coil. The ends of the movable coil, which consists of one turn of thick wire, dip into mercury cups to enable the current to traverse it. This movable coil is suspended by a filament, which is surrounded by a spiral spring, one end being attached to a milled head carried by the frame of the instrument and the other to the coil. The latter has attached

to it a pointer which indicates upon a circular dial marked in degrees. This pointer has a restricted play between two pins fixed to a dial, which can be well seen in Fig. 72. The end of the suspension thread passes free through a milled head to a point of support. It is evident that, if the pointer of the movable coil indicates zero on this scale, it will, on passing a current, become deflected and move towards one of the set pins. If the current passes in the right way, this deflection will be to the negative side of zero. In order to take a reading the milled head must be turned till the pointer is brought back again to zero. By doing this the spiral spring receives torsion, and the amount of this measures the current passing. The needle attached to the milled head enables a reading in degrees to be obtained of the amount of torsion which has been given in any particular case. If the value in ampères is known for the first degree of torsion—and call this A.—then the value for any other reading will be the square root of the angle of torsion, in degrees multiplied by A. The instrument may be marked for direct reading, if desired, but generally it is issued with a scale marked in degrees and a table of reference to save time in making calculations. It will be observed that for every reading a fresh setting is required. Since the strength of the spiral spring is very constant for a long period of time, these instruments are very reliable; and because this ammeter contains no iron it is one of the very few which can be employed in

connection with alternating currents. When not in use it is desirable to free the spring from strain by turning the mill-head so that its needle, as well as the pointer, stand at zero. The instrument possesses the necessary adjustments, and a means of relieving the filament from the weight of the movable coil when out of use. There are usually two fixed coils, one of thick wire and one of thin, so that the instrument may give larger indications for small currents when

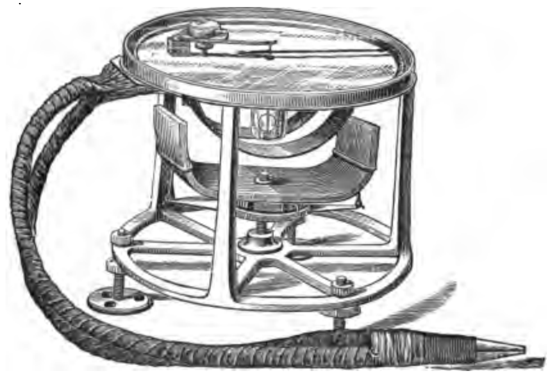


FIG. 74. MAGNETO-STATIC CURRENT METER.

required; and hence the reason for the three terminals shown on the base, the centre one being common to the two coils. Clearly each coil has a different constant. To give a practical idea of the value of the constants; in electro-dynamometer, No. 2081, for the thin wire, the value of a reading $= \sqrt{}$ angle of torsion $\times$ .9392; and for the thick wire $\sqrt{}$ angle of torsion $\times$ 3.176. This instrument requires to be levelled before using.

If the setting back to zero, after a reading, is not resorted to, a permanent "set" is given to the spring. This can be corrected by a special adjustment.

Cunynghame's voltmeter is a portable form of Siemens. It is very compact, and the method of reading is similar.

Fig. 74 illustrates Sir Wm. Thomson's magneto-static current meter. In principle it is similar to Joel & Paterson's engine-house meter, but far more beautiful in design. The pointer and magnetic needle are suspended by a fibre, and the dial is, therefore, horizontal. A small fan is attached to the fibre to check oscillations. The permanent magnet (seen below the dial) can be raised and lowered, in order to alter the value of the divisions upon the scale. When once the height of the magnet is settled for a set of readings it is clamped, but is still free to rotate; and this is necessary, for the magnet must be rotated in order to bring the pointer to zero before a reading is taken. It will be observed that the current passes in and out, by conductors placed one above the other. This instrument requires to be levelled. This current meter is not dead beat, but can be made direct reading by adjusting the height of the permanent magnet, and needs occasional calibration. The instrument described has recently been improved in many details. All the instruments described so far are only suitable for direct current, excepting Siemens' dynamometer.

The most perfect instrument which has been devised for use as a standard is the balance ampère-meter of Sir Wm. Thomson, which may be described as a perfect standardising instrument unalterable by time, and, although

189.

extremely sensitive, great delicacy in handling is not essential. It can be used for direct and alternating currents. The standard deka-ampère balance is shown in Fig. 75.

This instrument measures from 1 to 100 ampères. It will probably suffice if only the instrument illustrated be described, since the other sizes are either the same or very similar in their construction. It consists of two fixed rings at each end of the base, and between each pair is placed a movable ring, these movable rings being rigidly attached to the ends of a bar. This movable portion is suspended, balance-fashion, from a fixed point by a number of very fine wires. These wires are so placed as to give the appearance of two very short and broad pendulum springs, placed side by side. Sir William finds that this mode of suspension has less friction than other methods. This suspension being divided, permits the current to enter the movable portion through the one part and leave it through the other. The current traverses the whole of these rings successively, which may consist of one or more turns of wire.

Consider the action of a pair of fixed rings upon the movable one between them at one end of the instrument. The direction of the current within these rings is so arranged that the movable ring is attracted by one fixed ring and repelled by the other. The effect produced by the rings at the other end of the meter is similar, and the direction of the current in them is so arranged as to increase the effect produced on the other side. Consequently, when a current is passing, the movable rings become displaced from the

horizontal position in which they were approximately in the first instance.

At the extremities of the balanced portion there are bars, each of which bears a pointer, and these indicate upon two scales, one fixed at each end of the slate base. These bars also support an aluminum scale, which has two sets of divisions engraved upon it, and also a bar with a slider. This slider carries different weights, and the divisions upon the scale have values, which vary according to the weight placed upon the slider. The slider has a finger which points to the two sets of divisions upon the scale at the same time: the lower set is employed for accurate readings, the upper gives approximate values in ampères direct. This upper set of divisions is termed by Sir Wm. Thomson the "inspectional scale," and for all ordinary purposes the readings obtained upon it are sufficiently accurate. The true values are ascertained by doubling the square root of the reading upon the lower scale, which is engraved on a piece of aluminum separate from the upper scale. The lower scale has notches, to show the true positions, corresponding to the numbers upon the inspectional scale. In order to obtain a reading when a current is passing through the instrument, it is necessary to pull the slider along the scale until the movable rings take up the horizontal position, which is indicated by the position of little pointers on the suspended portion upon the scales attached to the ends of the base. Thus the weight, so to speak, balances the current. The right-hand end of the movable portion carries a small pan,

into which is put a suitable weight to counterpoise the one that may be placed upon the slider when at zero. The slipping of the weight into its proper position is effected by an ingenious self-releasing pendant, which hangs from a hook attached to a sliding platform. The latter can be pulled in either direction by means of a silk cord. The instrument has adjustments for obtaining the true zero point, and also is supplied with levelling screws. The useful range of each instrument is from 1 to 200 times of the smallest current, for which it was intended. The instruments are sent out with four pairs of weights; one pair is used for each setting, one for the sliding weight, and one for the counterpoise. In the deka-ampère balance shown in the illustration, the first pair make the readings, per division, upon the inspectional scale, .25; second pair, .5; third, 1.0; fourth, 2.0. The values are multiples of an ampère. A glass cover, not shown in the diagram, is placed over the instrument, and this carries a magnifying glass.

A new instrument has just been issued by Sir William and called by him "Ampère gauge." The readings are direct, and a checker is provided to reduce the oscillations of the pointer. The apparatus is suitable for alternating, as well as for direct currents. The principle depends upon an iron core, consisting of a soft iron wire being drawn into a special form of solenoid made up of flat copper discs, insulated from one another with mica. A pointer is actuated by the movements of the iron core, so that readings are given upon a scale.

Complete instructions are sent out with all Sir W. Thomson's instruments, issued under his own supervision.

All Sir William Thomson's instruments are beyond reproach, and his genius is so great that no one dares to criticise his labours. He is certainly to be regarded as our modern "Newton," and a man whom England should be proud to own as hers.

There are many other current-measuring instruments, which, however, might be termed indicators rather than measuring instruments, such as that of Mr. Henry Crookes, dependent upon the temperature to which a piece of metal is raised and shown by means of his heat-indicating paint. There are also others, which depend upon temperatures and chemical principles; but they are not employed for practical work.

The chief forms of ammeters having been touched upon, attention may now be directed to a few of the leading forms of voltmeters. The ordinary form of these instruments is similar to the majority of the ammeters described, with the sole distinction that their resistance is very high, so as to permit only of a very small amount of current to pass, and to give a large indication upon the scale for very small variations in the current passing. It is usual to adjust the resistance upon these instruments, so that a current may pass not exceeding one-tenth of that which would be required for a 16 c. p. glow lamp suitable to be employed upon the circuit, whose E.M.F. the voltmeter is intended to measure. Frequently its resistance is twice and thrice this amount. Consequently, if a voltmeter is wound with wire sufficiently large to bear the current constantly through it, without becoming too hot, the current employed to obtain a continual indication is very small.

There are a few special forms which deserve particular notice.

Fig. 76 is an illustration of Siemens' voltmeter. The readings in this instrument are taken in a method similar to that of the dynamometer already described. But its principle depends upon the current passing through suitable placed coils acting on a suspended permanent

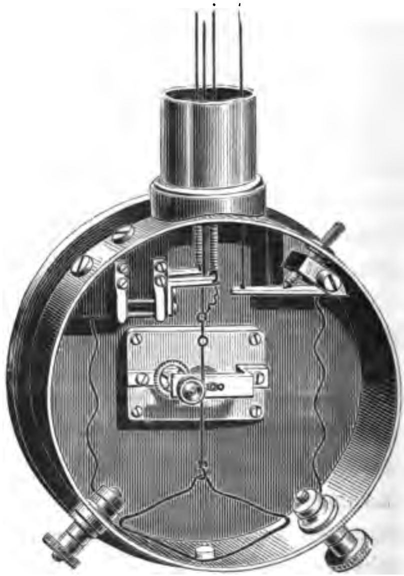
FIG. 76. SIEMENS' VOLTMETER.

magnet in connection with a spiral spring. Before taking a reading, the instrument must be rotated upon its base until its suspended pointer comes to zero. There are the usual adjustments. A box of resistances is always employed with this voltmeter, and the setting of the plugs alter the values of the divisions upon the scale according to the wish of the operator. The

graduation of the scale is such that no table of reference is required. The instrument is not suitable for alter-

FIG. 77. CARDEW'S VOLTMETER. (General View.)

FIG. 78. CARDEW'S VOLTMETER. (Showing Interior.)



nating currents. The pressure of these latter currents may be measured by a special form of dynamometer.

The following three instruments are suitable for measuring both direct and alternating currents :—

Fig. 77 is a general view of Major Cardew's voltmeter. Its principle depends upon the expansion of a fine wire made of fine platinum silver, having a diameter of ·0025 inch. By means of a spring this wire is kept in a state of tension when cold, as well as when it is hot and expanded during the passage of a current. It is evident that, if this wire were passed over a pulley, the latter will rotate for any change in the length of the wire; and if the pulley carries a pointer over a scale, measurements of the variations in the length of the wire become possible. These indications are proportional to the temperature of the wire. The temperature of the wire depends on the current, and the current on the pressure. Such is the principle of the instrument. The fine wire has a very great length, and, to make this instrument more compact, it is carried over a series of pulleys supported on rods, up and down, enclosed in a metal tube. The tube keeps draughts away from the heated wire, which would render readings impossible. The length of the rods varies with temperature, and in some instruments they are built up of different metals and in such a way as to act like a compensated pendulum. There is inside the case a fuse to protect the wire. The mechanical indicating portion is very similar to that of an aneroid barometer. An adjusting screw for obtaining true zero, or for calibrating, passes through the case, and is seen in Fig. 78, which is a view of the interior of the case. Fig. 78 is the view as seen from the back when the cover is

removed, and for the sake of space the long tube is not shown.

A resistance box is employed when the instrument is used for reading high E.M.F. Since there are no magnets or coils in the instrument, it may be read accurately near currents and masses of iron. This meter is almost dead beat and very sensitive. There have been many improvements recently made with the view of obtaining the greatest accuracy, and an improved method of replacing the fuse, when needed, without the slightest difficulty; whereas, in the original forms the task was a most difficult one, owing to the fineness of the fuse wire. The steadiest readings are obtained when the tube is placed horizontal, since up and down currents of air, within and outside the tube, are avoided, the scale naturally being shifted to suit this position. If a Cardew voltmeter is always employed to read at a small range of its scale, it can be completely depended upon, but is rarely correct over very large ranges. Major Cardew says that this must arise from faulty construction in the instruments, but it is difficult to decide whether it is due to this or to the fact that, if the wire is generally expanded to a definite length, its proportional lengths for other temperatures become altered in the same way as mercury does in a thermometer. The current may be kept on continuously, and the indications are dead beat.

In Ayrton & Perry's hot-wire voltmeter the principle is similar to that of the Cardew, but it is much more compact in form. Variations in the length

of the wire, the ends of which are fixed at each end, are measured by the sag, which is taken up by a spring and measured upon a dial by means of one of their special forms of spiral spring.

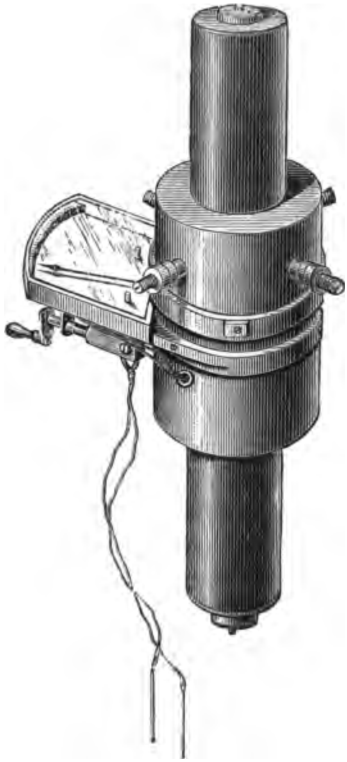


FIG. 79. SIR WILLIAM THOMSON'S MARINE VOLTMETER.

The new form of Ayrton & Perry's hot wire voltmeter is simple in the extreme. The arrangement

consists of a stretched wire under torsional strain, which carries a pointer indicating upon a scale. When the wire is heated by the passage of the current the twist in the wire becomes less and the pointer indicates the fact. In this way the E.M.F. can be measured.

It is fair to Major Cardew that the author should mention that some years ago he devised this very same form of apparatus. A carbon filament replaced the wire, and a mirror took the place of the pointer, using the "dot of light" method to obtain the readings.

Sir Wm. Thomson has recently brought out two forms of voltmeters, one very similar to his induction-balance, but the indications are shown by a long pointer upon a scale. He calls this instrument the engine-room voltmeter. The other, which is very portable, is termed "The Marine Voltmeter," of which an illustration is given in Fig. 79. It consists of a stretched piece of platinoid wire, which carries a small oblate of soft iron, situated in the centre of a solenoid of fine copper wire. Fixed to this piece of iron is a pointer which indicates on a scale. Resistances are used in connection with this instrument, in order to vary the value of the divisions upon the scale, as may be desired. Its principle is that the oblate tends to rotate its equatorial plane parallel to the lines of force in a uniform magnetic field.

The pointer is fixed to the oblate in such a position, that when pointing to zero upon the scale, the equatorial plane of the oblate is inclined about 45° to the lines of force of the solenoid. To obviate disturbance from

outside forces, the solenoid has a massive tube of soft iron around it, cut away at one part to permit the pointer to pass through and indicate on a scale outside the case. To stop the vibrations of the needle, when taking a reading, an ingenious checker is provided. The necessary adjustments are found upon the instrument. It may be left with the current continuously on. In these voltmeters the resistance is about 1,000 ohms when employed for measuring 100 volt currents.

The electro-static voltmeter of Sir W. Thomson, for measuring high E.M.F., has been modified for measuring low E.M.F. When the apparatus is required for the latter purpose, the quadrants and vanes are numerous, and the instrument is called multicellular electro-static voltmeter. One set of quadrants is fixed, and the other set is mounted upon a spindle, which carries a pointer for indicating upon a scale. The latter quadrants or vanes are movable. When a difference of potential exists between the fixed and movable quadrants, the latter move, so as to increase the overlapping of the two sets of quadrants, *i.e.*, a tendency to increase the capacity of the condenser, and motion is produced. This instrument takes no current from the circuit, and its waste is confined practically to leakage only, which is nominal.

Instruments exist for indicating watts, *i.e.*, volt-ampères, some of which are made for reading at the time, whilst others are self-registering. These are termed variously watt—erg—power—horse-power—meters. In all cases the indication shown at any

moment is the product of the ampères passing through the instrument by the pressure of the current. They are constructed on more than one principle. To give an idea of how the result may be produced, one of the methods may be described. It may easily be seen that if two coils, one suitable for an ammeter, and the other for a voltmeter, and connected to the circuit in these ways, be placed at right angles to one another, and a magnetic needle swing, at the common centre of the coils (carrying a pointer to indicate upon a scale), this needle will be moved by the combined effect of the current passing through the ammeter coil, and that passing through the voltmeter coil. Since these results can always be obtained by multiplying the ampères by the volts found by the readings of an ordinary ammeter and voltmeter, which exist in all installations, watt-meters are rarely employed.

For measuring the amount of energy delivered over a period of time, there are many meters corresponding to gas meters. All of them depend upon one principle, namely, an electrical apparatus working a train of wheels which revolve indicating needles over dials, the revolutions being faster or slower according as more or less current is passing. The full meters generally used are termed current-meters, since they take no notice of the pressure of the current. But there are forms of meters which take this into account, when the reading gives, not the quantity of current which has taken, but the quantity of energy consumed. When the current in the mains is at a fairly constant pressure,

it is necessary only to know the quantity of current which has passed through the instrument. But, where a meter is employed to ascertain what payment should be made to a public company, the simple registration of current delivered is manifestly unfair, for its pressure may, at times, have been below the normal pressure contracted for; so that, in these cases, either a meter indicating energy should be employed, or a strict public surveillance must exist, in order to compel every public company not to permit the pressure to fall below that contracted for, in the same way as gas companies are treated.

Ferranti's meter is one of the best current measurers, being one of the most simple and reliable as yet made. Its action depends on the rotation of mercury in a special form of apparatus, the speed rotation varying with the amount of current flowing through it. A fan, consisting of a piece of wire bent Z fashion, placed upon a spindle, floats on the mercury and revolves with it, and the spindle is in connection with the indicating train work. The magnetic field being a closed one, its readings are not disturbed by currents and masses of iron in its proximity. Other forms of current meters exist. Some depend on magnetic properties; others require clockwork to produce the readings, by vibrating a pendulum or creating some other movement, the speed of which is regulated by the current passing at any time.

Professor Forbes and others adopt as their principle the heating properties of the current. In some of the pendulum meters it is required to wind the clockwork by hand.

The principle of pendulum meters is as follows :— One pendulum swings uninterruptedly at its own period, and the rate of vibration of the other is disturbed by the current passing through the instrument, special arrangements existing to effect this, this disturbance having a definite relation to the quantity of current passing, or energy, if constructed to register this, at any moment. The movements of the two pendulums are integrated upon a dial or dials.

Ayrton & Perry's Erg-meter and the meter (Dr. Aron's) used by the Kensington Court Electric Light Supply Co. are worked on the pendulum principle.

In one form of instrument the measurements are made by the evaporation of ether.

Edison's meter is a thing of the past. It is a chemical meter, depending upon the deposit of some metal. This instrument requires a shunt resistance, and, therefore, is wasteful for large currents.

Many years ago, the author constructed a very accurate meter by means of a ray of light falling upon a mirror attached to a suitable ammeter, and the ray reflected to a focus upon a moving strip of sensitized paper. The darkened curve was afterwards integrated. Such an instrument, however, would be too complex for general use.

We finally come to the question of wiring. It is best to obtain highly insulated wire, braided on the outside, for small as well as large leads. The wire should have ninety-six to ninety-eight per cent. of copper in its constitution. The section ought to be chosen proportional to the current it has to carry, and always large enough

to take safely twice or three times the intended maximum current. A thousand ampères to a square inch of copper is generally considered well within the margin of safety. For small wires two or three thousand ampères per square inch may be passed; but this is not recommended. On the other hand, for very large cables, a thousand ampères to the square inch of section is too large a current, especially when they are cased in, since the surface for radiation is too small, and since they are excluded from a free current of air. The insulation should consist of cotton, next to the wire, overlaid with separate coatings of pure and vulcanised rubber, and braided on the outside. When specially high insulation is required, many servings of the rubbers are given, with cotton between each, and sometimes tarred tape is wound between some of the coatings. The chief object in having the cotton close to the cable is to prevent the rubber compounds entering between the strands of copper wire, which considerably increases the time required in making joints and connections on account of the large amount of cleaning necessary to remove the rubber adhering to the wires. Many makers tin the wire of the cables to facilitate the soldering of the joints, and to prevent the vulcanised rubber from acting prejudicially upon the copper when in contact with it. In many samples of cable which have come under the notice of the author, the tinned wire has parted by corrosion, in damp as well as in dry situations. This, he concludes, must be due to the tinning process, since it has occurred in no single instance with

untinned wire. Pure rubber is most durable in damp situations, and the vulcanized in dry. Consequently, if the cables are coated with both these substances, the double advantage exists. Under no circumstances should gutta percha be employed, for this is a most perishable article unless kept under water. Lead-covered wire should be avoided on account of the difficulty in making secure joints with it. Also, if electrical communication should exist between the outer covering of lead and the core, an enormous "earth" surface is at once given; and it is very difficult to obtain this class of cable with perfect insulation, because, in the process of drawing the lead over the cable, small minute cavities are apt to be produced in the insulation. No doubt the day will come when the manufacture of these cables will be brought to perfection, and then their use will become very extensive. But, in any case, they must not be employed where rats are likely to have access to them; for these animals are well known to gnaw lead-piping.

All wires and cables should be so laid that a small distance intervenes between them. The circuit should always be complete, in order that the current may be everywhere carried by insulated wires. Hence measures must be taken not only against the possibility of short circuit, but also against damp, which causes leakage and injures, first the insulation, and then the wire. Cables can be obtained which may be laid in water, but their expense is considerable. Much trouble is saved in tracing wires if the positive leads are red and the negative black. So

great is the advantage that manufacturers now make cables in these two distinctive colours. The best way to lay all cables and wires is in wooden slips, grooved with as many channels as there are wires to be run; or with two grooves, each containing one or more leads of the same polarity. The front is then covered with thin wood which is screwed on, to permit of easy removal at any time. Care must be taken that these screws enter the wood clear of the wires. Saddles of leather, made from old belting, answer well to keep the wires in position. In damp places, such as cellars, the wood casing should have a coating of pitch before the wires are fixed; and the wires themselves, when laid, may receive a coating of the same substance. The covering strip of wood is, in damp situations, best fixed, not close, but a quarter of an inch away from the channelled wood so as to permit a current of air to pass. Outside mains may be carried in waterproof pipes laid in the ground, which are best made of ordinary iron gas tubing, as this secures the mains from damage likely to occur, should the ground require to be opened for any purpose. When mains have to be laid outside the precincts of a house, it is always advisable to resort to underground work, in order to prevent the possibility of mischievous persons or burglars from tampering with the cables. When outside mains are laid overhead with long spans, it is desirable to support their weight by a strong stretched wire made of iron, phosphor bronze, or some other suitable metal, by means of special shackles shown in Fig. 80.

S S represents the supporting wire, C C the conductor, R R rings on S S, and W W the supporting portions which hold the cable.

Joints should be avoided in damp places, and, in all cases, they should be well made, perfectly insulated, taped, and rendered waterproof with one of the many

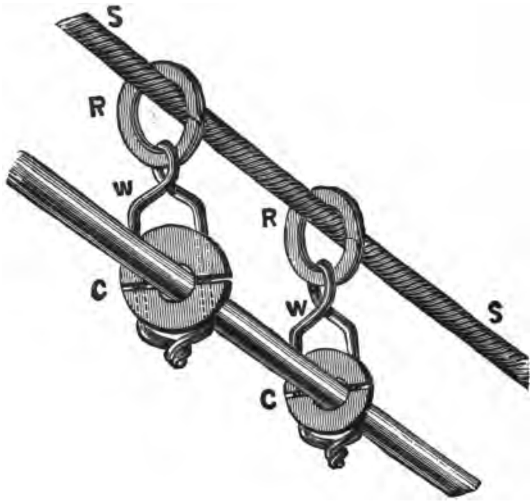


FIG. 80.

good compounds sold for this purpose, of which the well-known Chatterton's compound is probably the best.

Too much stress cannot be laid on the necessity for making the joints thoroughly. Joints are an endless source of trouble, unless made mechanically and electrically in all respects as good as the conductor itself.

Resin is commonly in use in this country for a flux, acid for making joints being regarded with disfavour.

All mains and branches ought to be laid on a system, and should start at centres. This is convenient for testing at any time, or for running new branches. Wherever a branch starts of smaller section than the main or branch whence it is derived, a safety junction should be inserted; and, if extra security is desired, these fuses may be placed in both leads.

To avoid danger, in the event of leakage at any time, it is advisable that all fuses should be placed conveniently for the purpose of examination or renewal. In rooms ready decorated, the wires may be laid without casings, except in places within reach, say, six or eight feet from the floor. If the wires are fixed about one inch apart above the picture-rods and under the cornice, they will then be completely out of sight. In houses wired before decoration, the casings may be laid level with the plaster or form one of the mouldings of the skirting, dado, or cornice; but the wires should always be easily accessible, and ought never to be laid in the walls or under floors, unless positively necessary.

In almost all instances casing is desirable. The casing cover may be moulded to suit the decorations of the room; its presence therefore need not be unsightly, and, when placed in angles, its existence passes unnoticed. The objection of laying wires under floors is the possibility of the nails, which fix down the boards, passing into the casing containing the wires and injuring the latter, and the danger arising from

any water being upset over the floor entering the casing. In old houses it is all but absolutely necessary to lay the leads in this way; and, in such an event, care should be taken that the casing containing the wires is fixed at a considerable distance below the floor-boards. By such means the nails will not reach the casing. All cables laid under floors should be very much larger than the size actually required, so as to prevent the necessity of having to relay them at any future time, should more lamps be added to the installation, or should the lamps be changed for others giving a higher illuminating power.

Where leads of any kind cross iron pipes or girders, and pass through floors and partitions, great care is needed in order to give proper protection to them at such places. Where wires must cross one another or pass through a floor, or partition, proper precautions should be taken to keep them apart, and to prevent their approaching anything of a combustible nature. For example, in traversing wood framework, an earthenware or metal pipe to pass the wires through ought to be used. Casing may be rendered fire proof by painting the wood with asbestos paint, or with a solution of tungstate of soda. Many specimens of asbestos paint are not fire proof, so no reliance must be placed upon the paint to be used until its qualities have been proved by experiment.

When cables pass through holes in walls it is a common practice to fill the space around the cables with Portland cement. This substance is likely to injure the insulation.

The best method is to use plaster of Paris, and face it with Keen's cement, and further with a coating of india-rubber in solution (benzole is a good solvent) if the place is exposed to the weather. Sometimes it is easier to apply Portland cement, and when this becomes necessary the cables should be wrapped in rag, india-rubber sheet, or tarred tape, so that these substances may be acted upon by the cement, instead of the coverings of the cables themselves.

Mains are often laid having no insulating covering. The bare copper must then be carried on insulators, and be protected in some way, such as by being laid in troughs or otherwise.

In the next chapter, the rules for the prevention of fire risks deal further with the question of conductors. It may be pointed out that considerable difficulty has been found in preserving the insulation upon the leads in old houses infested with rats. There are, practically, only two ways of overcoming the difficulty. The cables must either be laid in iron tubing, or coated with some substance which may contain poison, which shall be distasteful to those destructive animals ; so that they will be deterred from meddling with the cables at all. Even mice and black beetles are sometimes a source of annoyance, and when this occurs the precautions mentioned should also be applied.

In every instance a plan of the wires, with all details and positions of joints, should be made. If any wires outside the house are not underground, lightning guards should be employed ; otherwise, there is danger during

thunderstorms. When high E.M.F. is used, protection against danger to life may, in the majority of cases, be secured by "earthing" one of the mains; but only in such instances should this be resorted to.'

A very ingenious and simple plan devised, in France, for turning a lamp on and off at two places has been published in one of the electrical journals. (See Fig. 81.)

Let A and B represent the mains, C the lamp, D and F two two-way switches placed at two points where they are required to be used; E and G are the fingers of the switches; J, K, L and M, the contact pieces; and H and I the two leads, to complete the circuit, containing the lamp, one only being in use at a time.

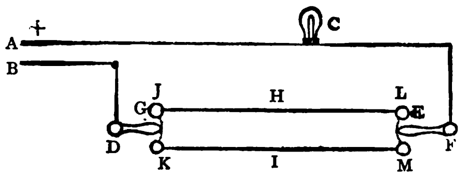


FIG. 81.

Now, if finger G stands on J, and finger E on L or M, the lamp will be alight; and it may be extinguished by the use of either switch, the only condition necessary for the operations of lighting and putting out the lamp being that the fingers G and E must always be on a contact piece. This will invariably be the case, if the switches have a suitable snap action.

It is, therefore, evident that the lamp may be turned on or off at either switch, without the necessity of touching the other. This principle applies equally when

more than one lamp is required, for the main A C may be laid in parallel system to maintain several lamps ; or many of the latter may be placed in series.

This system might be extended to place switches at four or more places.

Lamps can be placed in series, parallel, or in some combination of the two. In all methods, except the parallel system, high pressures are required. Therefore, for house lighting, the parallel system is almost universal. The series methods take an important place in certain classes of lighting, such as for factories, and for certain public uses.

To give a general idea of the parallel system, let it be assumed that twenty lamps are to be used from a dynamo. Suppose, that from one dynamo terminal, twenty wires start, and each wire has a similar lamp placed in its course before being returned to the other dynamo terminal, let every branch have an equal resistance. Then we have the current on leaving the dynamo, dividing into twenty courses, lighting twenty lamps, all equally bright, because, as the resistance of each circuit is equal, equal currents traverse them. This is the parallel system, but in practice, to start all lamp circuits from a point, is neither possible nor convenient ; consequently, long and large mains are laid, one from each terminal of the dynamo ; and no connection exists between these mains except by branches connecting them, in the course of which the lamps (motors or other apparatus) are placed. The resistance of the mains is so small, as compared with that of each branch with its

lamp, that the resistance between point and point, whence the branches start, may be neglected, and we return to the equivalent of the first arrangement, where all the branches were supposed to start from the dynamo. It is also evident that, when the lamps at every point are required to be equally bright, large mains become a necessity, apart from the question of carrying the current safely; and they must also be larger in proportion as the E.M.F. of the lamps is lower, since the resistance of each branch and lamp is smaller; and, consequently, their resistance, compared with that of the mains, has a lower ratio. Hence the higher the E.M.F. required for the lamps, the more equal is the light given from each lamp, in all parts of the system, even though smaller mains were used. In order to have absolutely equal light from similar lamps on every branch, it is necessary to make a series of calculations for finding the proper sections, which should be given to each branch, so that the resistance of each lamp circuit measured from the dynamo terminals shall be equal. In practice, however, such precision is not demanded; for when all the conductors are laid in accordance with the rules, which have already been given, and which are further touched upon in the next chapter, the difference in brilliancy of any lamp from the others would be inappreciable.

High volt lamps blacken less than low volt ones, which is a great point in their favour; and they are quite as lasting if not overrun.

With alternating currents the lamp globes blacken

more than with direct currents, and the lives of the filaments are shortened.

The Incandescent lamps used at the present day almost universally are those made by the Edison and Swan United Electric Company. They consist of an exhausted glass globe containing a very fine filament of compact carbon, which has a very high resistance. The ends of this filament are brought electrically at a short distance apart, to the outside of the globe, by being cemented to two platinum wires, which pass through the glass, where they end in loops or some other suitable attachment for connecting to the lamp-holders which are joined to the conductors. As yet platinum appears to be the only metal that can be sealed in glass, and does not permit of air following its course, thereby destroying the vacuum. When a metal is heated, its resistance becomes greater ; but, with carbon under this condition, its resistance becomes less, consequently, the amount of current, which a lamp will take in practice, cannot be calculated by measuring the resistance of the filament, when the latter is cold. When the filament is heated it passes through the usual stages of dull red heat to white hot ; and, if further heated, the distinct outline of the filament is no longer seen. At this point, the filament is said to be in a state of irradiation ; and this in its proper incandescing point ; if further heated, a faint violet light fills the interior of the globe, due possibly to gases (probably H gas) being given up from the platinum, and finally the filament breaks. The length and section of the filament

determines its light-giving power, and lamps which require 60 watts for 16 c.p. are supposed to last at least 2,000 hours, if a higher E.M.F. is not employed than that for which they were intended.

Terminals for apparatus and switchboards are made on a great variety of patterns, and the designs should be chosen according to circumstances; for there is no

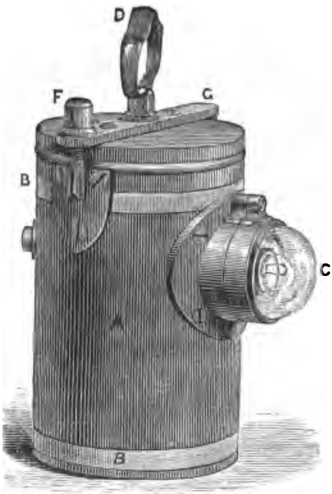


FIG. 82.

one pattern which can be considered equally convenient for all purposes.

It may be advantageous to be possessed of a portable electric lamp, which may be used as a carriage reading lamp, or for any other purpose. The Edison and Swan Co. make a lamp of this kind intended for mining, but applicable for general use. It is shown in

Fig. 82. A represents the wooden case, B B the strengthening rings; G is the hinge of a metal strap which carries the lid and the handle D; this strap is secured by a nut at F; C is a glass front to protect the lamp. A switch exists upon the side of the case not shown in the figure.

The case contains four small secondary cells joined together as shown in Fig. 83.

On inserting the cells into their case, the contact is

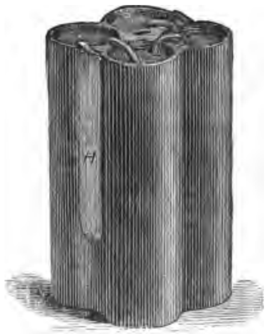


FIG. 83.

made between them and the lamp circuit by means of springs pressing against lead pieces, one of which is shown in the plate at H. Proper instructions are sent out with these lamps for charging them; and this can be done from the ordinary house lamp-circuit by inserting a lamp or resistance in the course of the leads going to these cells, such lamp being suitable to work with the E.M.F. of the circuit, and capable of passing the charging current required.

CHAPTER III.

RULES FOR THE PREVENTION OF FIRE RISKS.

THE last chapter partly dealt with the dangers likely to arise from a badly laid installation, and here the rules issued by the Institution of Electrical Engineers are set forth in full for the benefit of those who may wish to consult them. The author feels some reserve in criticising these rules, for, having been a member of the Committee, it would not be acting in good faith to make public many of the pros and cons which arose in the discussion of each rule before its present form was settled. The rules are very general, because it was found absolutely impossible to provide for every emergency which might arise, without drawing up, what would actually have become, a voluminous specification for the contractor. This was never intended, and would no doubt have pressed hardly on the electric lighting industry, as well as on the users, by insisting on most stringent regulations, simply because at times special cases might warrant them. Two or three points of interest may be remarked upon.

Rule 1 is excellent, and speaks for itself. Even under

the maximum limit mentioned there, if 150° F. is not reached, no good insulation existing is injured in the slightest degree. On this point the Committee had ample evidence, and this rule is better than any one previously published for ascertaining the required sectional area in all cases. The old rule of 1,000 ampères to the square inch section can rarely be applied, for very small wires will carry three times this quantity with safety ; and large cables must carry less than that permitted by the 1,000 ampères rule. The temperature method settles all points. A special paraffin wax, softening at 130°, may be employed as a rough but very practical thermometer. Too high a temperature causes the insulation to give off vapours, which can be perceived by the sense of smell ; but such heating should be avoided, because the insulation would be injured. It was also shown that Rule 4 was a good one, and was generally complied with.

There is still a great difference of opinion, in reference to the use of cut-outs, as to how far they should be multiplied. Some experts consider the fewer there are of these apparatus the better, while others argue in the contrary direction. One thing, however, is quite certain : if the construction of the lamp holders, and any apparatus that may be employed on the lines, is such that by no possibility can a short circuit be produced in renewing a lamp, or during any other operation, also provided the wires are properly laid, so that no short circuit can occur in the mains or branches, fuses may be completely dispensed with, and a number of bad contacts avoided.

These improvements must be waited for, and, though slowly, they will surely come.

However, every motor, unless its present construction be completely revolutionised, should have a cut-out; for in these machines a short circuit is always possible. Access to the motor itself is frequently necessary, and at such times, if care is not exercised, a short circuit may be created. This might occur on other occasions, but at those times such accidents may be prevented by enclosing the motor in a case. All motor covers should be so made as to freely admit the air to the motor, in order that its circuit may be kept cool, and lined with a fire-proof lining.

As electric lighting becomes more general, and experience is gained, so trained men, and improved apparatus, will arise for this special trade. Then the danger of fire will be found to be no greater than when using gas, with the additional safety of freedom from explosion, and many of our present precautions will be ridiculed as uncalled for.

There is danger which cannot be met by fuses: it is the possibility of a conductor breaking, and the ends remaining in close contact, thus setting up an arc. In a single-wire conductor, the lamp will burn dull and give an indication of this occurrence, but it does not necessarily follow that, because a lamp is dull, an arc exists; for other causes may produce it. In houses, all conductors carrying over two ampères should, as a general rule, be of stranded cable, so that the possibility of the breakage of one conductor setting up an arc shall not

occur. Stranded cable also permits of short turns, without risk of fracture. On the other hand, very small wires are probably best in the unstranded form.

Every day brings fresh experience, and an accident, which occurred in the author's workshop, may here be recorded with the view of preventing such mishaps in future. An experimental lamp was attached by a flexible twin cord to a wall connector, which had no switch of its own, the only connector in the installation so arranged. The switch on the lamp was off, so no current passed. On his entering the workshop one evening, he found the twin cord in flames, the fuse remaining intact. After the fire had been extinguished, a careful examination of the cord was made, and it showed very imperfect insulation. At one point the two wires had become bare, and there an arc had been started, which eventually fired the insulation and its covering. A rapid contact and separation must have occurred to set up the arc, for only 100 volts existed on the lines, and this infinitesimal quantity of current started the fire.

But for the good fortune of having discovered the occurrence at its outset, there can be little doubt that a serious fire would have resulted.

The moral of such accidents is not to dread electricity, but to have all wire, used in flexible twin cords, well insulated, and never to have the current on such wires except when required, which may be effected by placing a switch in connection with every wall, and other connector.

It cannot be too strongly pointed out that the leakage of electricity can only be detected by testing with proper apparatus, and not by the sense of smell in the same way as gas. Under some circumstances, a leakage may be observed by the sense of touch, but naturally this is not one which should be relied on.

With regard to transformers, although much information has recently been forthcoming on the subject of these apparatus, in consequence of the important place they are now taking in the distribution of current for public purposes, yet there is a great deal more to be done; and, as our leading electricians are now devoting all their energies in this direction, it may be hoped that before long the best methods of using and constructing such apparatus, together with all the laws which regulate them, will become as well understood as are now known concerning continuous currents and their apparatus.

The great disadvantage under which the public have been suffering, and still suffer, is that all central station authorities declare their system perfect and satisfactory, whilst their customers complain of bad service. At present the law can attack only those companies which are licensed or have underground systems, and until overhead wires can also be controlled by some Government department the grievance will continue. Heavy penalties should be imposed upon electric lighting companies, payable partly to the State and partly to the aggrieved consumer, for every breakdown, accidental or otherwise, and for every variation of pressure exceeding

2 per cent. on the house mains. Any variation exceeding even 1 per cent. shows a marked difference in the light of an incandescent lamp, and, if frequent, would soon injure the eyesight. A very small fall of E.M.F. below the normal makes a vast difference in a light. With a 10 per cent. fall, a lamp will give barely half the light it was intended to give, although only one-tenth less current is passing. It is evident that, if the payment for current is to be fair, any company giving a pressure of 10 per cent. under that contracted for should receive a reduction of 50 per cent., and not of 10 per cent., in the payment, because the consumer does not care what energy he is taking : it is the light which he requires, and for which he is willing to pay. Since no company is likely to agree to such terms, it is of the highest importance that a public authority should exist to protect the public against any variation of pressure in the mains from that stipulated for, in the same way as is at present done with gas companies. These remarks, when they appeared in a previous edition, were considered as very severe, but they have been fully justified by the result of recent Board of Trade enquiry under the direction of Major Marindin, which has shown the positive necessity of protecting the public by some adequate regulations ; and it is certain that a bill will at once, or very shortly, be introduced into Parliament for carrying out the recommendations contained in the report, and any others that may be thought necessary, and to confirm the Board of Trade model order. When this bill becomes law, the consumer's interests will

be zealously guarded by the Board of Trade. This measure is likely to produce a great extension in the use of the electric light, and a better feeling will probably prevail than at present between the supplying companies and the public in general. Although, under Government surveillance, the regulations are likely to be stringent, electric lighting will in no way be impeded, for only first-class companies could live, and public confidence would soon be extended to the new illuminant as it is now given to gas.

Rules and Regulations for the Prevention of Fire Risks Arising from Electric Lighting.

Issued by the Society of Telegraph-Engineers and Electricians.

Revised and Remodelled from the Rules issued by the Society in 1883, and from other sources of information both home and foreign, and recommended by the Council in accordance with the Report of the Committee appointed by them to consider the subject.

MEMBERS OF THE COMMITTEE.

Professor W. G. Adams, F.R.S., *Past President;* Professor W. E. Ayrton, F.R.S., *Vice President;* Sir Charles T. Bright, *Past President;* E. B. Bright; R. E. Crompton; W. Crookes, F.R.S., *Vice President* Dr. J. A. Fleming, M.A.; Professor G. Forbes, F.R.SS. (L. and E.); Professor G. C. Foster, F.R.S., *Past President;* Edward Graves, *President;* J. E. H. Gordon, B.A.; Dr. J. Hopkinson, *Vice-President;* Professor D. E. Hughes, F.R.S., *Past President;* W. H. Massey; W. H. Preece, F.R.S., *Past*

President; Sir David Salomons, Bart., M.A.; Alexander Siemens, *Vice-President;* C. E. Spagnoletti, *Past President;* James N. Shoolbred B.A.; Augustus Stroh; Sir William Thomson, F.R.SS. (L. and E.), *Past President;* Major-Gen. C. E. Webber, C.B. (ret.), R.E., *Past President.*

These General Rules are drawn up with the object of reducing to a minimum, in the case of the electric light, those risks of fire which are inherent to every system of artificial illumination, and also for the guidance of those who possess, and those who contemplate having, electric lighting apparatus on their premises.

It is to be understood that these General Rules are not intended to supersede any Detailed Rules which Fire Offices may issue for their own protection.

It would, therefore, be desirable that, before the electric light is used, notice should be sent to the Fire Office in which the building is insured, in order that an opportunity may be given for inspecting the installation.

The chief difficulties which beset the electrical engineer are internal and invisible, and they can only be effectually guarded against by testing with special apparatus and electric currents; they arise from leakage and from bad connections and joints, which lead to waste of energy and the production of heat to a dangerous extent.

In addition, the difficulties arising out of defective and inefficient apparatus are numerous; they must be understood and guarded against.

The necessity cannot be too strongly urged for guarding against the presence of moisture, which leads to loss of current and to the destruction of the conductors and apparatus by corrosion and otherwise.

Injudicious connections of any part of the circuit with the

"earth" tend to magnify every other source of difficulty and danger.

Many of the dangers in the application of electricity arise from ignorance and inexperience on the part of those who supply and fit up inadequate plant, and frequently from injudicious economy on the part of the user.

The greatest element of safety is, therefore, the employment of skilled and experienced electrical engineers to specify the method in which the work is to be done and the quality of the materials to be employed, and to supervise the execution of the work.

Conductors.

1. They must have a sectional area and conductivity so proportioned to the work they have to do, that, if double the current proposed is sent through them, the temperature of such conductors shall not exceed 150° F.

2. The conductors, or their casings, should be placed in sight if possible; and they should always be as accessible as circumstances will permit.

3. Within buildings they should all be insulated; and this rule applies equally to all conductors and parts of fittings which may have to be handled.

4. Whatever insulating material is employed, it should not soften until a temperature of 170° F. has been reached, and in all cases the material must be damp-proof.

5. When leads pass through roofs, floors, walls, or partitions, and where they cross or are liable to touch metallic substances, such as bell wires, iron girders, or pipes, they should be thoroughly protected by suitable additional covering; and where they are liable to abrasion from any cause or to the depredations of rats or mice, they should be encased in some suitable hard material.

6. In the case of portable fittings with which flexible leads are used, special precautions must be taken.

7. Conductors should be kept as far apart as circumstances will permit, the spacing between them being governed by their potential difference.

8. When conductors are carried in very inflammable structures, precautions should be taken to isolate them therefrom.

9. Conductors which are protected on the outside by lead, or metallic armour of any kind, require the greatest care in fixing, on account of the large conducting surface which would become connected to the core in the event of metallic contact between them.

10. In cases where conductors pass into a building, from one building to another, or from one room to another, precautions should be taken to prevent the possibility of fire or water passing along the course of the conductors.

11. All joints must be mechanically and electrically perfect, to prevent heat being generated at these points. When soldering fluids are used in making joints, the latter should be carefully washed and dried before insulation is applied.

12. Under all circumstances complete metallic circuits must be employed. Gas and water pipes must never form part of the circuit, as their joints are rarely electrically good, and, therefore, become a source of danger.

13. Overhead conductors, whether passing over or attached to buildings, must be insulated at their points of support. Precautions must be taken to obviate all risk of short-circuiting where they are likely to touch a building or other overhead conductors and wires, either by their own falling or by being fallen upon by other conductors.

14. In the case of overhead wires, every main should have a lightning protector at each point where it enters or branches into a building.

15. Metal fasteners for fixing conductors should be avoided; but, when unavoidable, some additional covering should protect the conductor from mechanical injury at such fixing points.

16. The insulation of a system of distribution should be such that the greatest leakage from any conductor to earth (and, in case of parallel working, from one conductor to the other, when all branches are switched on, but the lamps, motors, etc., removed) does not exceed one five-thousandth part of the total current intended for the supply of the said lamps, motors, etc.; the test being made at the usual working electro-motive force.

17. It will often be found a great convenience and assistance in the prevention of accidents if the positive lead be coloured differently to the negative, or made otherwise distinguishable.

Switches.

18. Every switch or commutator should be of such construction as to comply with the following condition, namely—That, when the handle is moved or turned to and from the positions of "on" and "off," it is impossible for it to remain in any intermediate position, or to permit of a permanent arc, or heating.

19. The handles of every switch must be completely insulated from the circuit.

20. The main switches of a building should be placed as near as possible to the point of entrance of the conductors, or to the generators of the current if they are within the

building itself. Switches should be provided on both leads.

21. Switch-boards should bear clear instructions for their use by the inexperienced.

Electrical Fittings Generally.

22. Switches, commutators, resistances, bare connections, lamps, etc., must be mounted on incombustible bases. Cut-outs mounted on bases of wood rendered uninflammable are admissible. Vulcanite bases are undesirable in damp situations. The cracking of porcelain and earthenware fittings is a source of danger which can be avoided by precautions in fixing.

Cut-outs.

23. All circuits should be protected with cut-outs; and all leads from the mains, or small conductors from larger ones, must be fitted with cut-outs at their branching points.

24. Where fusible cut-outs are used, the section should be so situated within its frame that the fused metal cannot fall where it may cause a "short-circuit" or an ignition.

25. For all main conductors a cut-out should be provided for both the "flow" and "return," and the two fusible sections must not be in the same compartment.

26. The flexible leads of portable fittings must in all cases be protected by cut-outs at their fixed points of connection.

Arc Lamps.

27. Arc lamps must always be guarded by lanterns or netted globes, so as to prevent danger from ascending sparks and from falling glass and incandescent pieces of carbon.

28. All parts of the lamps and lanterns which are liable to be handled (except by the persons employed to trim them) should be insulated.

THE DYNAMO.

29. The armatures and field-magnet coils should be thoroughly insulated. Dynamos should always be fixed in dry places, and they must not be exposed to dust flyings or other industrial waste products carried in suspension in the air. They should not be permitted in the working-rooms of mills, where the liability to such danger exists, or where any inflammable manufactures are carried on or inflammable materials are stored.

30. Motors should be subject to the same conditions; but when it is necessary to use them in positions such as those above referred to, they must be securely cased in, such cases having a non-combustible lining.

BATTERIES.

31. Both primary and secondary batteries should be placed and used under the same precautions as prescribed for dynamos; and the room in which they are placed should be well ventilated. The batteries themselves must be well insulated.

TRANSFORMERS.

32. When these are used to transform either direct or alternating currents of high electro-motive force—that is, from or to an electro-motive force of, say, 200 volts—they, together with their switches and cut-outs, must be placed in a fire and moisture-proof structure—preferably outside the building for which they are required. No part of such apparatus should be accessible except to the person in charge of their maintenance.

33. In all cases conductors conveying currents of high electro-motive force inside buildings must be specially and exceptionally insulated, cased in, and the casing made fire-proof.

34. The positive and negative terminals connected to such conductors should not be permitted to be nearer each other than 12 inches.

35. Transformers which, under normal conditions of load, heat above 150° F. should not be permitted to remain in use.

36. Transformers should be so constructed that under no circumstances whatever should a contact between the primary and secondary coils lead the high E.M.F. into the building.

MAINTENANCE.

37. The value of frequently testing and inspecting the apparatus and circuits cannot be too strongly urged as a precaution against fire. Records should be kept of all tests, so that any gradual deterioration of the system may be detected.

38. Cleanliness of all parts of the apparatus and fittings is essential to good maintenance.

39. No repairs or alterations must be made when the current is "on."

All the above rules, for the reduction to a minimum of the risks from fire, are also applicable in principle to installations of electricity for other uses than that of lighting; they also include precautions necessary to avoid risk of injury to persons, whether the conductors and apparatus are situated inside or outside a building.

The following are some rules, which have been issued by Sir Wm. Thompson, regarding personal safety, when using his instruments on circuits having high E.M.F. :—

PRECAUTIONS FOR SAFETY IN THE USE OF SIR W. THOMPSON'S ELECTROSTATIC VOLTMETERS.

BY SIR W. THOMPSON.

§ 1. In all applications in which one of the two conductors connected with the voltmeter is kept permanently connected with the earth, this conductor should be connected with the outer case of the voltmeter. The other conductor is to be connected with the insulated terminal, and must be carefully guarded against accidental contacts.

§ 2. To provide for use in any application not fulfilling the condition of § 1, all the electrostatic voltmeters are supplied with thoroughly insulating feet; and the precautions stated below in § 3 and § 4 must be observed.

§ 3. The vertical scale voltmeter for from 400 to 12,000 volts, when set up for permanent use, should be enclosed in a case (which may be of wood with a glass front) preventing any person from accidentally touching the metal case or the terminals of the instrument. The vibration-checker is worked with perfect safety by a silk cord passing through a hole in the wood or glass of the protecting case to the front outside. For temporary or experimental applications the user must take his own precautions; an outer enclosing glass case might be found too cumbrous.

§ 4. For ordinary domestic electric lighting or other applications to less than 200 volts, the multicellular voltmeter may be left unprotected so far as personal danger is concerned; but, to avoid chances of damage to instruments

or wires, or of melting a fuse, its outer case, as well as its terminal insulated from the outer case, ought to be perfectly guarded against accidental contacts when the instrument is set up for permanent use. Glass and vulcanite sheaths are provided for this purpose by the instrument-maker when desired.

§ 5. *General Warning.*—Never open the case of the vertical-scale voltmeter to change its weights, nor touch its terminals to connect or disconnect (or to secure either connection if imperfectly made), without being sure either that the dynamo is not running, or that both the conductors leading to the voltmeter are safely disconnected from its circuit.

§ 6. It may be asked, with reference to the vertical-scale voltmeter, why is the inner case made of metal? The answer is, that the electric conditions for definiteness of measurement require the vane to be protected all round from sensibly disturbing influence of any substance, other than the air around it, differing in potential from itself, unless at the same potential as the quadrants. Why, then, not coat the metal inner-case with wood or vulcanite, or other non-conducting material? Answer: The protection thus imagined might be delusive when 10,000 volts is dealt with. Safety is most surely secured by an outer case an inch or so from the inner metal, unless, *which is always best when it can be arranged for*, one of the conductors is kept connected with the earth, and with the metal case of the electrometer also connected with the earth.

CHAPTER IV.

ACTION OF CELLS WITH DYNAMO.

It is clear from what has gone before that, when a dynamo is charging the cells, the E.M.F. on the lines is raised at least ten per cent.; and this may cause injury to, or may break, the lamps. This rise of pressure is of no consequence, when charging ceases before lighting hours; but in general there is no certainty of this being done. Therefore, measures have to be taken to keep at all times the E.M.F. within the proper limits, on the house mains. The methods for doing this are described in the next chapter, but it is necessary here to point out the circumstance.

Dynamos give different E.M.F.'s for different currents taken from them, when running at one speed. These variations may be drawn, diagramatically represented by curves called "Characteristics;" and every dynamo has its own peculiar curve. A perfect machine would give the same E.M.F. for all currents, when running at one speed; and the curve would become a straight line. Good dynamos have curves approaching this form for all currents within their capacity. The

shunt-wound dynamo is best suited for charging an accumulator. The series and compound-wound dynamos are liable to have the polarities of their field magnets reversed, should the E.M.F. at the terminals approach very near to, or fall below, that of the cells, when great damage may be caused before the cut-outs have had time to act. Messrs. Elwell Parker manufacture a "Special Compound" wound dynamo, for use with cells; but it is best to have the right thing at once, instead of resorting to makeshifts.

In a series wound machine, the E.M.F. rises with an increased current; in a shunt-wound dynamo, the reverse takes place, and the compound machine is wound partly series, partly shunt, so that the E.M.F. is practically constant at a particular speed for all currents. Only the shunt dynamo claims special attention here. This dynamo has a falling curve (*i.e.*, the E.M.F. falls as the current in the outside circuit is increased) due to three reasons. First, the armature absorbs more E.M.F. as the current is increased; second, as the outside resistance is lowered, the shunt current becomes less and the field weakens; third, the current in the armature reacts upon the field. As the outside resistance is increased, the E.M.F. rises to the work. Many have supposed that a shunt machine will always respond to the work in a definite and suitable manner. This is not the case in good dynamos, because by reason of their construction (consult Professor Sylvanus Thompson's book on the subject) the curve is nearly straight for all currents

within their capacity ; and such modern dynamos are in general use, although those with falling curves have certain advantages in small installations, where waste is not of great consequence. If the terminals of a shunt dynamo are short circuited, no current flows, because no current traverses the shunt circuit to create a field.

Dynamos give a different E.M.F. in proportion to the speed, but, if a much higher E.M.F. be required than was originally intended, then two things must be considered. The first is to ascertain whether the armature is strong enough to withstand the increased speed; and, secondly, whether it will not become necessary that the shunt resistance should be increased by inserting an outside resistance, to prevent too much current passing and the wire becoming too hot. In dynamos intended to run at two speeds, it is usual to place the shunts parallel for slow rates, and series for fast; in this way the use of an outside resistance is avoided. The E.M.F. and speed are not exactly proportional, for, as the E.M.F. rises more current is sent round the field magnets, and the field becoming stronger, the E.M.F. has an increase due to this cause also, inasmuch the iron of the magnets is not near saturation point in modern dynamos, except where they have been made for some special purpose. Yet, within small limits, the speed and E.M.F. may be taken as varying together directly, after the speed, for which the machine was intended to run, has been reached. The relations between the speed (limited by the strength of the armature),

field, and resistance of the armature, are the data which determine the E.M.F. and curve; and the diameter of the armature wire limits the current, which can be produced without injury to the machine. The general behaviour and qualities of the dynamo have now been considered.

As to the cells, it has been shown their E.M.F. is practically constant, but rises somewhat as the charging proceeds, and mostly at the end of the charge.

Three things may occur when the dynamo and cells are combined.

1. The dynamo may have an E.M.F. higher than that of the cells. In this event, they will charge.

2. The E.M.F. of the two may be equal, consequently, no current passes.

3. The E.M.F. of the dynamo may be less than that of the accumulator. In this case the cells will discharge into the machine, and run it as a motor. Appliances should be placed in the installation to prevent this.

Since the mains are branched from the ends of the accumulator—or, in other words, it would be more correct to say that the house and dynamo leads are one and the same, with the accumulator placed between them, in the same way as a lamp—it is necessary to examine what occurs when a current is flowing in these mains. Case 3 may be passed over, because, should it occur, it must be regarded as due to neglect or accident.

In case 1, it is evident that, so long as the E.M.F. is higher than that of the cells, all currents going to

house mains must come from the dynamo: this, in fact, supplies the light and charges at the same time.

In case 2, half the current is supplied from the cells and half from the dynamo. But it does not, in practice, necessarily follow in this proportion, unless the resistance of the dynamo leads be extremely small and the internal resistance of the battery very low.

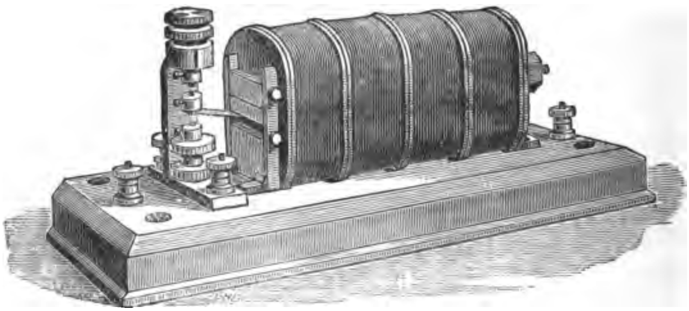


FIG. 84.—E.M.F. REGULATOR (REPULSION).

There is, however, one more case in considering the house leads. It is possible to raise the E.M.F. of the dynamo slightly above that of the cells, so as not appreciably to charge them, and yet supply the current to the house. This the author terms "balancing point," and the advantage is gained of obtaining a steady light. The charging current must not be switched on until the E.M.F. of the dynamo is higher than that of the cells, say from 5 to 10 per cent.; and the proper moment to switch on may be ascertained by observing a voltmeter. For the voltmeter, may be substituted two lamps similar

to each other placed side by side, one lit from the dynamo and one from the cells, as proposed by Mr. Melhuish. The current is switched on, when the lamp lit from the dynamo is observed to be the brighter one. But the best way is to have an automatic switch putting on the current when the correct E.M.F. is reached. Such an instrument consists of the E.M.F. regulator (Fig. 84), which sends a current to a mercurial switch (Fig. 85) when the E.M.F. is sufficiently high, and another current when it falls below the proper amount; thus making or breaking, by means of this controlled switch, the dynamo and accumulator circuit. The switch is made two-way to permit the current from the dynamo, when the charging circuit is broken, going through a resistance, passing a current equal to that for charging the cells, whereby shock to the machinery is avoided. Hence no difference is produced in the load at the moment of putting the current to the accumulator. These instruments have never failed in the author's installation, and probably no existing automatic switch is so sensitive, good, and reliable.

The construction of the E.M.F. regulator (Fig. 84) is as follows. A coil having a resistance of about 4,000 ohms surrounds two soft iron bars, one movable horizontally, being pivoted. For convenience the coil is divided into four sections, and is joined, voltmeter fashion, at those two points upon the mains, where the changes of E.M.F. are to actuate the instrument. The bars of soft iron are bent thus in side view, and cross one another, appearing so

Where these cross, the iron is cut away to permit of their being placed in this manner, so that the bars may face one another throughout their length. It will be noticed that, when a current passes through the coil, the whole system will become magnetic; and, in consequence of the peculiar form given to the bars, the movable one will be displaced by repulsion and not by attraction, since the polarities at each end of the instrument are the same for both bars, the effect at one end being doubled by that at the other extremity. The movable bar at one end carries an adjustable weight similar to that of a steelyard. At the other, it carries a short rod to which is attached a contact arrangement consisting of a holder with a thick wire of platinum in it. This movable swinging contact piece may touch an upper or a lower platinum contact fixed to the frame of the instrument. Its action is thus: in a 100 volt installation, if the weight is so adjusted that when 110 volts is the pressure of the current traversing the coil, then the swinging contact touches the lower fixed contact, and a current passes through the movable arm to this fixed contact, and onwards through a wire to one end of the coil upon the magnet forming part of the controlled switch, which has the other extremity connected with the opposite lead, thereby causing the switch to act and place the dynamo on to the accumulator. When the E.M.F. falls below 108, the repulsion between the fixed and movable magnets is no longer powerful enough to overcome the weight, and the movable contact comes against the upper fixed contact, and a current is

sent to the magnet coil on the controlled switch through another wire, which causes it to act in the reverse way, and the dynamo is taken off the cells. All contacts are platinum, for this wears far longer than any other material and does not oxidise in the air, so their surfaces remain bright. The weight may be adjusted

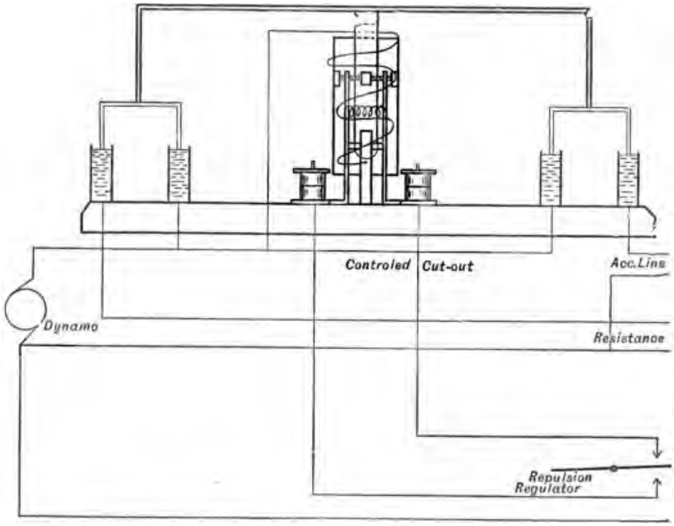


FIG. 85.—CONTROLLED SWITCH OR CUT-OUT, SHOWING CONNECTIONS.

for the instrument to work at any other E.M.F., but, if employed on circuit of very low pressure, naturally the coil would be wound with a lower resistance. The difference in the pressure between the putting on and taking off the cells from the dynamo is regulated by adjusting the distance between the upper and lower fixed contacts

which permits of the movable contact having a longer or shorter free swing. The longer the swing the greater will be the difference. It is evident that, when this regulator is used for charging purposes, the whole time this operation is continuing the swinging contact will remain touching the lower fixed one, and *vice versâ*. This is particularly pointed out here, because the same instrument is employed in the method, described in the next chapter, of obtaining constant E.M.F.; but the distances between the fixed contacts and the movable one will no longer be regulated so as to assume the positions just mentioned.

Fig. 85 is a general diagram of the controlled switch or cut-out. Its action is identical with Cunynghame's magnetic cut-out, except that it is a two-way switch. When the switch is on the one side, the current is put from the dynamo to the cells, and, when on the other, from the dynamo to a resistance. It must have been observed, in the description of this cut-out, that when the magnet has drawn the armature towards its pole through a certain distance, it is essential that the current in its coil shall be cut. To fulfil this condition in the controlled switch, a special arrangement is added in consequence of the instrument being two-way. This addition consists of two contact levers, which make or break the magnet circuit when required, and is accomplished at the proper times by the moving armature.

As the E.M.F. of the cells rises and opposes the charging current, tending to lessen it, so also does the E.M.F. of the dynamo in a falling curve machine; but

in the best machines this rise is inappreciable. Therefore, if the current is to remain constant, certain devices in the form of governors must be introduced. A method of altering the E.M.F. of the dynamo is to place resistance, in and out of the shunt circuit, by hand. In this way a fairly constant current can be obtained.

A very neat form of resistance is one recently brought

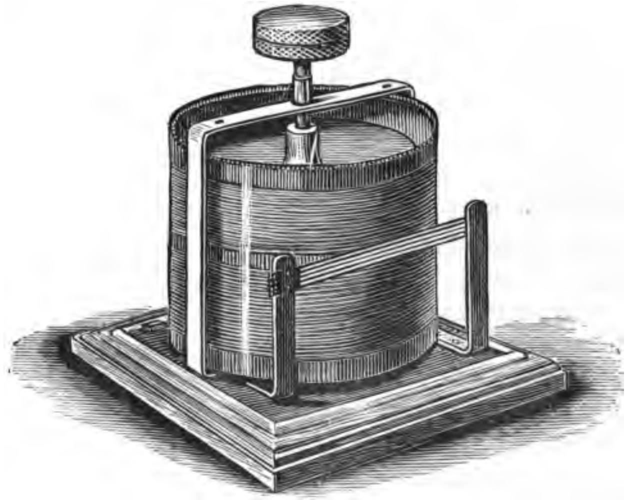


FIG. 86.

out under the name of Wirt Rheostat. Its construction is exceedingly ingenious.

Fig. 86 represents the apparatus. It is very small, and can be employed, when suitably wound, for raising and lowering the light of incandescent lamps, for voltmeter resistances, as well as for the purpose indicated.

It might be supposed that a constant current dynamo

would be the right thing for keeping the charging current constant. This is true, if charging is not done during lighting hours; but, when this is not the case, such a dynamo is unsuitable. It is also less efficient than are the usual forms.

The automatic means of keeping the current constant will be explained in the next chapter.

The resistances required to be inserted for this purpose are small, compared with that of the shunt. Consequently, the characteristic of the machine remains unaltered; and sparking is not produced at the commutator, if the brushes have been set for the load.

The cells tend to steady the light when the prime motor is slightly irregular in speed, at such times when no current is flowing through them; also when they, as well as the dynamo, are delivering a current to the lines. It is then that the field, for the armature to turn in, is kept constant; and the variations of E.M.F. only will alter for any irregularity of speed, instead of variations of speed and field combined. At other times, also, the cells steady the light, but not to the same extent. Their action in both cases depends on the relation between the resistance of the cells to that of the lines, so that any increase in current, due to a rise of E.M.F., is divided between the cells and the line in that proportion; and since the resistance of the cells is low, compared with that of the lines, the bulk of the increased current passes that way. Thus the current to the lines is kept nearly constant. It is, therefore, desirable to make the resistance of the

cells as small as possible, apart from the other reasons already given.

"Potential" is always understood as implying difference of potential, which is equivalent to difference of pressure, commonly spoken of as difference of E.M.F. between any two points, and is measured in volts.

The pressure of a current falls in direct proportion to the resistance that is traversed compared with the whole resistance of the circuit. For instance, if a wire, having a uniform section and 100 feet in length, has a current flowing through it, the difference of potential at its ends being 100 volts, then the difference of potential, at a point upon the wire 25 feet from one end, will be 25 volts from that end; at a point 50 feet from the end 50 volts; and so on, *i.e.*, the fall in the potential will be proportional to the *distance* the current has travelled along this wire. But if the wire had not been of uniform section, the fall would have been proportional to the *resistance* traversed, *i.e.*, the curve of the fall of E.M.F. along any conductor is a straight line, the resistance of a conductor, and not its length, being used as a unit of measure.

From this many deductions may be made, but there are two which claim special attention. The first is that any number of similar lamps may be placed in series, provided that the volts required to be employed with each lamp, multiplied by the number of lamps, equal the pressure between the leads. Thus, two 50-volt lamps, or four 25-volt lamps,

may be placed in series upon a 100-volt circuit. The difference of potential between the loops of each lamp being in the one case 50 volts, and in the other 25, the lamps must be similar, or they will not be worked under proper conditions.

The second deduction is that, if the plates in a battery are put farther apart, the E.M.F. on the lamp circuit (*i.e.*, effective E.M.F.) will decrease as the current increases, in a greater degree than when the plates are close together. This may not be evident at first sight, but the following considerations will make it clear. The greater the distance between the plates, the larger will be the internal resistance of the battery. Again, the larger the current flowing to the mains, the less must be the resistance of that outside circuit. Consequently, there is what, for this argument, may be taken to be a constant resistance in the battery, and a variable one outside; so that the proportion existing between the internal resistance of the battery and the resistance of the outside circuit is a variable one, and this proportion between the battery resistance and the outside resistance becomes smaller as the resistance of the outside circuit becomes less. Hence, more pressure is consumed in the battery as the current flowing in the mains increases, and the remaining pressure to be utilised in the outside circuit is proportionately decreased. These considerations limit, for practical work, the distance which may be given between the plates of an accumulator, because, if they were separated much more than at present, on taking the maximum current,permitted for any particular

size of cell, the fall of E.M.F. would be too great for lighting purposes.

As shown by the author, some years back, any counter E.M.F. arrangement of low resistance, placed between the lines, will steady the light when cells cannot be used, such as a motor kept steady by a fly-wheel, or doing constant work.

On more current being taken to the lines after the balancing point is reached, the dynamo and cells begin to supply equal quantities, since the E.M.F. of the dynamo falls slightly for the increased current, and the E.M.F. does not recover itself for this diminished current, because the strength of the field has been altered. It is evident, from all which has been said, that machines with very falling curves regulate automatically and very perfectly; but they are too wasteful in any but very small installations.

In all cases, consumers would do well to look to practical requirements rather than to efficiency. Efficiency is important in a large installation, but in a small one any waste is of no consequence compared with the advantages secured by a steady light and freedom from a break-down.

The following simple formulæ may prove of service in making the calculations so frequently required in connection with electric lighting.

Let $C =$ the current in ampères.

„ $E =$ E.M.F. in volts.

„ $R =$ resistance in ohms.

„ $W = CE =$ watts or power.

Then

$$C = \frac{E}{R}$$

$$E = CR$$

$$R = \frac{E}{C}$$

$$W = C^2R, \text{ because } CE = C^2R.$$

Hence the waste in a main varies as the square of the current. To give an instance: if the current in a set of mains is doubled, the mains must have their section increased four-fold, in order that the loss of pressure in passing through them shall remain the same as before.

1 Board of Trade Unit, B.T.U. = 1,000 watts.

746 watts = 1 horse power.

therefore 1 B.T.U. = $1\frac{1}{3}$ horse power.

1 horse power (H.P.) = 33,000 pounds raised one foot in one minute.

CHAPTER V.

METHODS OF WORKING AND GOVERNING.

It now remains to explain the best way to carry out the following requirements, which have been indicated in the last chapter: firstly, to make everything automatic; secondly, charging the cells at a constant current; and, lastly, to maintain a practically correct and constant E.M.F. in the house mains.

We have seen that the above results cannot be obtained except by the use of special devices. These will be considered in their order.

1. In the last chapter the way of putting the current to the cells automatically was there described, but in order to make everything self-acting two more conditions are necessary. One is to make the charging current constant by means of a governor; and the other is to have a governor to keep correct and constant E.M.F. on the lines. Maintaining a constant charging current necessitates a variable E.M.F., which, if not governed, is reflected on the lines, and, besides this, the charging E.M.F. is too high for the lamps; for had the E.M.F. of the charging current been made suitable for

the lamps, the E.M.F. would be too low from the cells when charging is stopped, unless some were shifted from parallel to series, which would eventually exhaust those cells, and such a method, therefore, is not desirable.

2. To keep the charging current constant, no matter what the counter E.M.F. of the cells may be, and at times when the house leads are being supplied from the dynamo whilst charging, no matter what the characteristic of the machine may be, can only be effected in one way, viz., by altering the E.M.F. at the terminals of the machine in such a way as to produce the desired result. A constant charging current is a great convenience in practice, for once adjusted no further attention is ever necessary; and the exact amount of ampère hours put into an accumulator is always known by the number of hours the machinery has run. A constant charging current may be obtained by speeding the dynamo for the highest E.M.F. ever likely to be called for, when giving maximum current, say, for instance, 25 per cent. more E.M.F. than the cells give. Then by employing a variable outside resistance, which can be placed in the dynamo shunt, by hand or automatically, the field may be weakened, and thus lower the E.M.F. The total resistance should be so adjusted that when the dynamo is giving ten per cent. of maximum current, the E.M.F. is about equal to that required on the house mains. In this way every possible pressure necessary may be obtained, since by varying the resistance every pressure between the limits mentioned may be secured.

It is also possible to insert variable resistances in one of the leads between the dynamo and cells; but it is a bad method, because it destroys the steadying power of the accumulator, and is very wasteful.

The loss by using resistances in the shunt is *nil*, because, although there is a waste in passing the shunt current through this apparatus, it is more than compensated for by there being no necessity to reduce the pressure of the main current after leaving the machine, the actual result being a very large economy.

3. To maintain a constant pressure on the house lines during charging hours, the only way is to reduce the charging E.M.F. to the pressure required for the lamps by means of some apparatus put in one of the house leads. This loss by reduction of the E.M.F. is absolutely inseparable from the system, during the time of charging; and the necessary lowering of the pressure can be effected by placing a variable resistance, moved by hand or automatically, in the course of one of the leads; a method which is not good, because the number of steps in the resistance must be very numerous, and the latter must be varied not only with a change of E.M.F., but also for every change of current passing to the house, though the pressure may remain unaltered.

By far the best and simplest way is that which the author devised some years back, viz., by putting counter E.M.F. in one lead in order to reduce the E.M.F. of the charging current for use on the lines. The chief advantage of this system is that only one setting is necessary for a particular reduction, and it is independent of the amount

of current flowing. Thus, if the reduction in the E.M.F. has to be four volts, a counter E.M.F. of four volts accomplishes it for all currents; but had resistances been used, a different adjustment would have been required for every variation in the current. The counter E.M.F. is produced by means of cells like those in the accumulator. A current passing through these cells in a contrary direction to that in which they would be charged has its pressure reduced at the rate of two volts per cell, and a two-volt jump is not noticeable at the lamps; because the changes are made automatically at the proper moment, and the variations can be limited to 1 per cent. in a 100-volt system. These variations could be effected by hand, but the automatic way is the best. Cells of a different construction could be used to give a counter E.M.F. of 1 volt, or less if desired. Plain lead plates may be employed, with water for the liquid; and such cells answer very well.

The old method was to place one of the lines from the end cell of the accumulator to some other, so as to include fewer cells between the lines, but leaving the whole of them in the dynamo circuit. Thus the excluded cells give a counter E.M.F. to the house current, which they have to carry, in addition to the charging current. Consequently, if they are not larger than the others, or have shunts, they receive too heavy a current and become injured. In any case the counter E.M.F. method is preferable, and under better control. Besides, every cell in the battery charges and discharges equally. In large installations both methods may be used together

with advantage in certain cases. In simple installations this excluding of cells is done by hand, but an automatic two-way switch should be employed, identical with the one used to put the dynamo current to the cells, and worked by the same E.M.F. regulator; only in this case the regulator causes the controlled switch to put one line from the last cell of the battery to some other cell, at the same moment that it works the charging switch, and the reverse actions take place on stopping the dynamo. Although two controlled switches are required, they evidently need but one E.M.F. regulator. It is clear that when much current is flowing in the house mains, the waste is less when the E.M.F. at the dynamo approaches the pressure required for the lamps. The charging current at such times is smaller, and at the same time greater steadiness is secured.

The constant current governor permits of this being done, if all the shunt resistance is allowed to be taken out after the dynamo gives a certain predetermined current, effected by proper speeding, and, in order to obtain these or other results in practice afterwards, it is only necessary to adjust the governor spring.

If great steadiness of light is required, when the dynamo is supplying the current to the lines, which also gives the economy above mentioned, the governor should be set to make the charging current very small, so that the dynamo may produce very little more current than is being used in the house. The best way to set a governor for this purpose is the following. A second resistance should be placed in the

dynamo shunt circuit and worked by hand, which is only to be employed when the above result is desired; and, on these occasions, the resistance is gradually and slowly inserted by hand. The governor then responds by taking resistance out, since it struggles to maintain the original charging current. Continue putting in resistance till the governor has worked out all its own; after that, every additional resistance put in by hand reduces the charging current. This method saves the operation of continually setting the governor for varying charging currents, which can be done, but is inconvenient to do at a moment's notice; whereas the hand resistance method is very easy, as it may be effected in practice by simply observing the ammeter, which indicates the charging current, and moving the switch handle that regulates the resistance, until the reading is found to be the one required. If it is always intended to work in this manner, it is possible to adjust the governor spring in such a way that the usual charging current is given till house lighting commences, when the effect of taking current to the lamp mains will reduce the charging current proportionally as the house current increases.

One way of securing economy is to charge before lighting hours.

Another way of securing economy is to charge at maximum and supply the house at the same time; but, if the prime motor is very irregular, in its speed, the steadiness of the light is not so perfect as in the manner of working just described. This second method applies to large installations, where, by

increasing the work, the machinery is run with greater efficiency. As to which method should be adopted must depend upon the discretion of the user guided by the circumstances.

Another benefit is derived from a counter E.M.F. governor, viz. :—

That, when the cells are disconnected for any purpose, the dynamo can be used without them, on the house

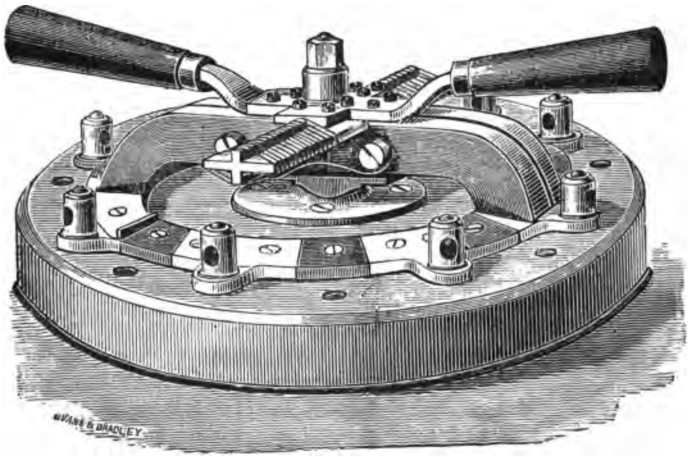


FIG. 87.—COMPOUND SWITCH.

mains, since the apparatus governs the E.M.F. perfectly by reducing all above the normal to the correct pressure necessary for the lamps.

Although, so far, only the advantage has been shown of a counter E.M.F. governor during charging hours, it is evident that the governing action is equally good at other times. Therefore, this apparatus not only

protects the lamps from damage during charging hours, and just after stopping, but also secures a steady light on all occasions.

A few extra cells are desirable, for use, in the event of the E.M.F. of the battery falling below the normal, should this ever happen. These additional cells are rarely necessary when a battery is properly attended to. The addition of extra cells requires an increased E.M.F. of the charging current, and therefore renders

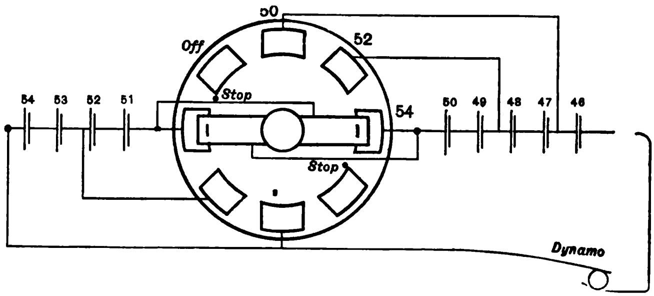


FIG. 88.—DIAGRAM OF CONNECTIONS. COMPOUND SWITCH.

a governor on the house line the more necessary; but the author has devised a compound switch (shown in Fig. 87) whereby this increased pressure of the charging current is dispensed with. When the charging and lighting are carried on at the same time, and the method of excluded cells is employed, these cells suffer no injury; which is a considerable advantage, and the extra cells are no longer idle. The method consists in doubling the number of excluded cells and placing one half of them in parallel with the

other half. For instance, suppose that the last eight cells are placed, four and four in parallel, giving eight volts; then, by moving the switch, these cells can be shifted to series giving successively ten, twelve, fourteen and sixteen volts, or to twelve and sixteen volts, without intermediate pressures, and all increases above eight volts are added to the E.M.F. of the battery. In this way the E.M.F. of the battery can be raised eight volts at any time, with no cells remaining idle; also when in parallel, and excluded from between the lines, twice the maximum charging current may be passed without doing injury.

The diagram (Fig. 88) needs no explanation. It will be only necessary for the reader to trace the connections to the various positions of the switch fingers in order to understand it. Fig. 87 is a general view of the switch employed, and will shortly be described.

When storage cells are added, or deducted one at a time by means of a switch without breaks, each cell is successively short-circuited, which causes a large spark on the switch contacts, soon rendering this apparatus unworkable and also spoiling the cells. When two or more cells are included in one shift, the trouble increases. If the short-circuit is made through a small resistance, the E.M.F. of one cell being only two volts, the spark is very slight, and no harm is done to the cell. If a current is flowing to or from these cells, when a shift is made, and the resistance is suitably adjusted, no spark is created. A compact form of switch, meeting the requirements just mentioned, for shifting

cells, has been devised by Messrs. Ayrton & Perry. This switch is made with two fingers close together with a very small resistance placed between them. The latter comes into use only when the fingers are moved, and are upon adjoining contacts. When a shift is made, both fingers must stand on one contact piece.

Other forms of this switch attain the same end, and one is shown in Fig. 89, where the resistances are placed in the base. There are dummy contacts

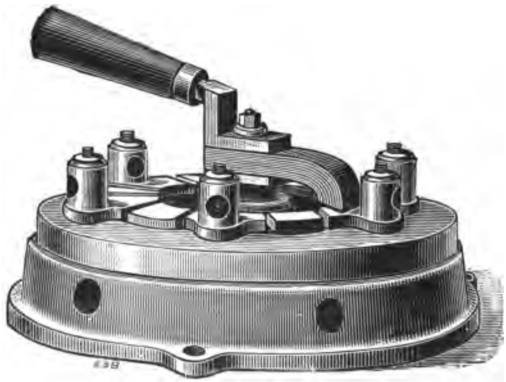


FIG. 89.

between the true ones, and a resistance is placed between every dummy and true contact, instead of one between two fingers, as in the switch last described.

Fig. 87 may now be explained.

The fingers are divided, and there are two supports of vulcanite fibre, each of which carries some thick wire, one coil being electrically placed between the two fingers on

one side of the centre, and the other coil correspondingly attached to the fingers on the other side, the fingers on each side being electrically independent of one another. As a result, the switch fingers may be moved from contact to contact without breaking the current and without burning the contacts.

It has hitherto been supposed that each step of the counter E.M.F. governor in the positive direction increases the counter E.M.F. If storage cells are employed in connection with the governor, then by the addition of a suitable piece of apparatus, instead of the counter E.M.F. being increased at each step in the positive direction, the inverse may be produced. This extra apparatus or automatic switch must reverse the connections of the wires on the cells end for end. Consequently, if a governor is capable of reducing the E.M.F. 30 volts, with such an addition it could also increase the E.M.F. 30 volts, and its total range would be 60 volts.

This is too refined for practical use, but the possibility of obtaining this large range is shown in the event of its ever being required.

The cells used for reducing the E.M.F. must contain sufficient plate surface to pass the maximum current without giving off large volumes of gas. The size of cells may be chosen by taking double the charging current which would have been employed, if they had been used for storage; and this will be the quantity of current which can be passed conveniently, *i.e.*, when used for the purpose of reducing E.M.F.

The steps of this governor must have no breaks, or the lamps will be extinguished during the shifts.

It may be seen that when storage cells are used to produce counter E.M.F. they are being charged at such times when a current traverses them.

We have, therefore, shown that to get perfect regulation and everything automatic, the following apparatus are required:

1. An automatic switch to put on the charging current, when the E.M.F. at the dynamo terminals is higher than that of the cells.

2. A governor to keep the charging current constant.

3. A counter E.M.F. governor to maintain a correct and constant pressure on the house lines.

For supplementary apparatus, the following may be placed in the installation:

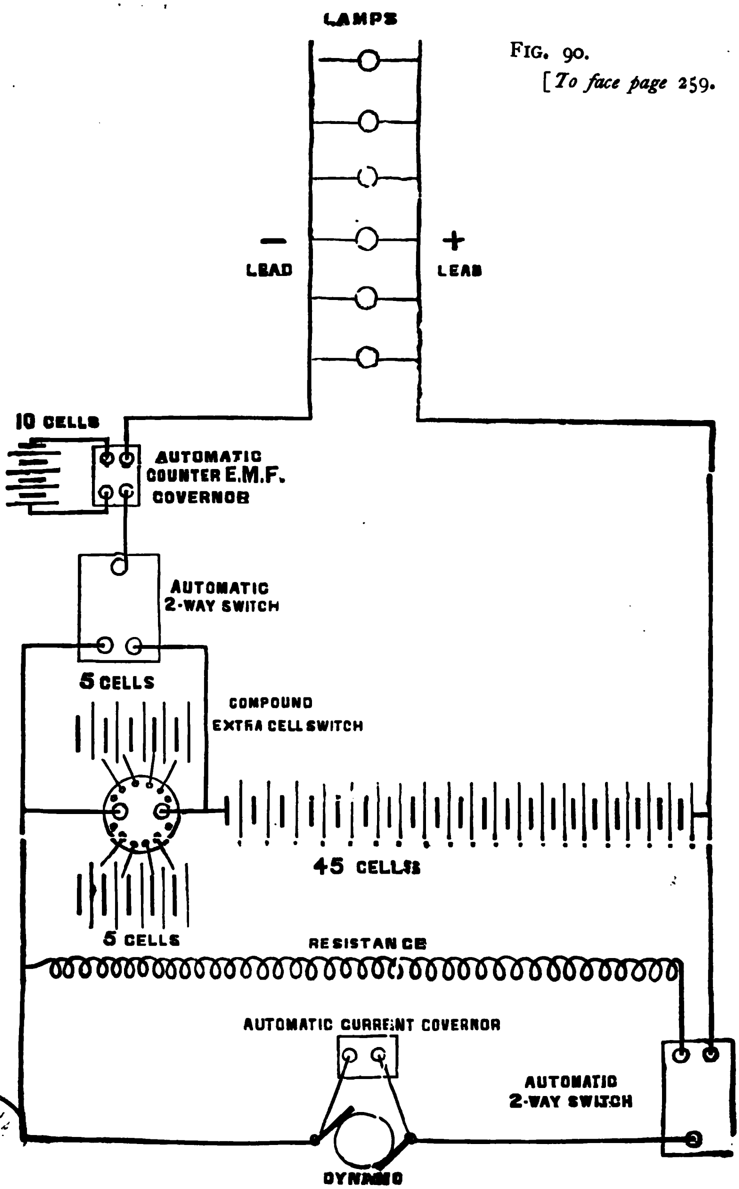
1. An automatic switch to exclude a given number of cells from between the lines when charging, should this method be employed.

2. A compound switch to increase the E.M.F. of the battery, by shifting cells from parallel to series, when required, in those cases where extra cells are used.

3. A hand switch, in connection with the constant current governor, to reduce the charging current on special occasions, without resetting the governor, when this method of working is resorted to.

With these appliances, it is only necessary to start and stop the engine, so that a man having no knowledge of electric lighting may be employed. Indeed, the stopping may be done automatically with a steam engine,

FIG. 90.
[*To face page* 259.



in the same way as was shown in an earlier chapter to be possible in the case of a gas engine, only with slight modifications.

The general plan of an installation, with automatic arrangements, is shown in Fig. 90, and speaks for itself.

It may be pointed out that, when a gas engine is employed, it becomes a very fair governor for the current from the peculiar nature of such engines, provided the engine is not too large for the installation, so that a constant current governor may be dispensed with. These engines tend to run at their maximum power, when the proper load can be given, and, in the case of electric lighting, this can usually be done, so that the watts given by the dynamo, if shunt-wound, are fairly constant throughout a run. The result of this is that, during the charging hours, the counter E.M.F., necessary to keep the pressure correct on the house lines, need not be much altered, so that a counter E.M.F. governor might be dispensed with; and all that is required is an automatic switch to exclude a definite number of cells at such times. But it must be distinctly understood that, when complete governing apparatus does not exist, the charging hours will be very much longer, since the current to the cells diminishes as charging advances and constant E.M.F. is absent.

In large gas engine installations the same governing arrangements are desirable as if steam engines had been employed; in small installations also when the power of the engine is beyond the requirements.

It not unfrequently happens, in small installations, that the E.M.F. at the dynamo terminals falls below that of the cells in consequence of much current being taken to the house lines before the operation of charging has been stopped. When this takes place, the dynamo commences to act as a motor, instead of as a generator. The result is, the cells are discharging into the dynamo, as well as to the lines, the gas engine being driven by the dynamo instead of driving it. This is generally discovered by the engine making very few or no explosions, also by the direction of the current as indicated by the charging ammeter. When this circumstance occurs, no one happens to be present, the evil continues.

The author has devised a piece of apparatus in order to remedy such a mishap should it arise. This instrument he calls an anti-reverser. It consists of a thick coil of wire capable of carrying the usual charging current. In the centre of the coil swings, vertically, a permanent magnetic needle. The arrangement, so far, is similar to one of the ammeters previously described. To the arbor of the needle is attached an arm ending in two prongs, each of which dips into a mercury cup. The charging current, on its road, passes through these cups, which are electrically connected by the prongs when they dip into the mercury. So long as the charging current passes the right way, the magnetic needle tends to move in such a direction that the fork remains in the mercury cups. But, in the event of a current of two or three ampères passing from the cells to the dynamo, the magnetic needle moves in the opposite direction, causing

the current to be cut in consequence of the fork being raised out of the mercury cups. An adjustment exists for any pre-arranged current.

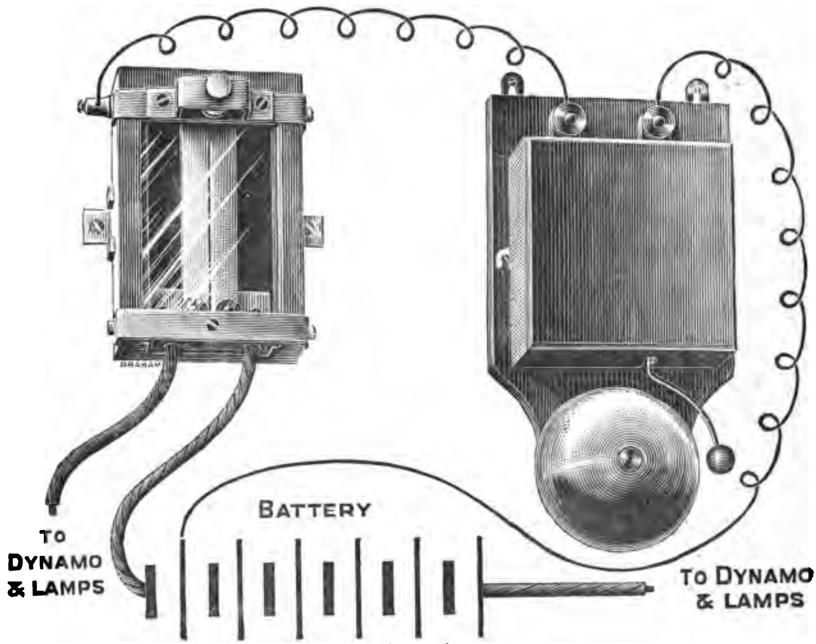


FIG. 91.—AUTOMATIC CONTRIVANCE FOR GIVING NOTICE WHEN MAXIMUM WORKING CURRENT IS REACHED.

In gas engine installations the engine may be started by using the dynamo as a motor, in which event starting resistances must be employed, and the brushes

pulled over to give a negative lead. The brushes must be gradually moved to the usual positive lead, as the speed of the dynamo increases and the engine begins to give explosions.

To bring under the attendant's notice the fact that the cells are charging at too high a rate, should such an event occur, an alarm may be employed consisting of a very low resistance coil placed in the course of the charging current. In this solenoid is placed an iron core, which is raised by the magnetic action of the coil as soon as the current goes beyond a certain point, when a contact is made, causing a bell to ring. This bell may obtain its current from one of the battery cells, and it is made to ring for any current by adjusting the weight of the iron core. Such an apparatus is made by the E.P.S. Company. To effect the same end, Messrs. Drake & Gorham have a device worked by the temperature produced by the current, but such appliances are more delicate.

Fig. 91 shows the latter instrument, with its connections. The apparatus is illustrated at the left of the figure, and consists of a compound metallic bar, which makes contact, thereby ringing the bell, by assuming a curved form when its temperature is raised by the current passing through it. The adjustment for contact when a certain current passes is effected by the little screw shown in the centre of the upper part of this apparatus.

There is really no need for these excess of current alarms where a constant current governor exists.

When too large a discharging current is taking place a cut-out goes and the house is in darkness. To prevent this inconvenience, an automatic arrangement could be added to the installation. The device would be as follows: When too great a current leaves the cells, a special form of two-way magnetic cut-out acts, putting a large resistance into the circuit, thereby reducing the current. When the current is brought within the proper limit, the resistance is automatically removed. What would happen in the house would be this. When too many lamps are put on, the light of all of them would suddenly fall, but they would not be extinguished; on reducing them to the permissible number, their brilliancy is restored.

An electrical governor on the steam engine is of little use for obtaining a very steady light, on account of the great momentum of its moving parts. All governors are best placed in connection with the dynamo and leads. Where an accumulator is used, a governor on the engine is of little value for constant E.M.F., as well as for constant current. It also costs more to put a governor on the engine than elsewhere, and its position there renders it more liable to injury. There is a phenomenon somewhat resembling momentum in the case of magnetism, but it can be reduced to such an extent as to be of no consequence.

A governor placed to regulate the E.M.F. or current of the dynamo may work fast or slow. It may "hunt," that is, fail to reply at once to the call made upon it, and this hunting, in practice, shows itself by passing and repassing the proper step on which the switch

finger should remain; but this is of no consequence, for steadiness is soon established. The "hunting" is caused by the time required for the iron in the magnets to respond to the altered shunt current. Hunting, in the case of an engine governor, is a serious matter, for then the engine alters its speed by fits and starts.

Before entering into the mechanical details of two first-class governors, the following special ways of working an installation will be explained. It may be truly said that for want of proper governors, or through some other reason, few installations really work perfectly in all respects. It sometimes happens in a small installation, where a gas engine is in use, that the dynamo and cells are both giving current to the lamps, and, under these circumstances, the light is frequently unsteady. The reason is that, under such conditions, the E.M.F. of the dynamo and cells is equal, or nearly so; and, since every irregularity of speed, which is considerable with gas engines, produces a rise or fall of E.M.F. at the terminals of the dynamo, the cells are, at one moment, giving all, or nearly all, the current to the lines, and perhaps even making a motor of the dynamo, and at the next the dynamo is giving all the current, and also possibly charging the cells at a very low rate. Consequently great strains are given to the cells and dynamo alternately, and the engine runs far worse than it would do in general. The case given is supposed to be a bad one, but the difficulty occurs in many degrees. A very simple remedy is the following, when a large number of lamps are required to be used at one time. Disconnect

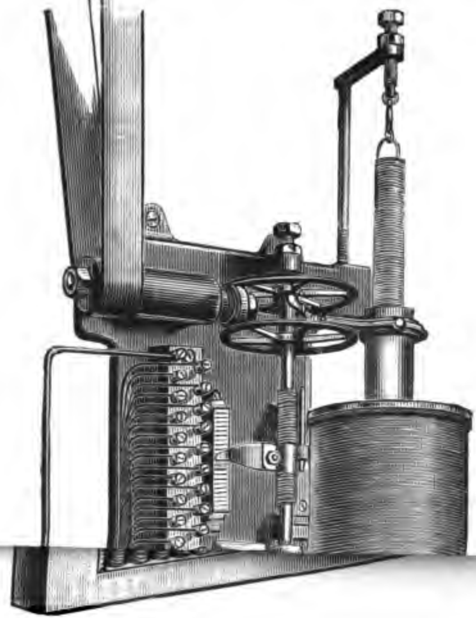


FIG. 92.—THE GOOLDEN AND TROTTER GOVERNOR.

[*To face page* 265.

the shunt wires from the brushes and connect them to the cells, so that the cells are discharging the whole evening into the shunt circuit. Such a current rarely exceeds 3 or 4 ampères, so that a constant field is obtained for a very small loss of charge. The lines also must be disconnected from the cells. The dynamo now gives all its current to the lamps, including that which usually goes to its shunt circuit. Thus the machine is made to give, without strain, more than its nominal output. This is the very best way to work, when the utmost power of an installation is needed, especially if the dynamo has a capacity equal to or greater than the maximum discharging rate of the accumulator. Even with smaller dynamos, this mode of working has many advantages. Naturally the changes of connections would be done by means of switches.

Another method, whereby the light would be quite steady if all arrangements have been well devised, is that of working at "balancing point," when the two steadying properties of the cells come into play. To work in this manner, the current flowing in the lines must remain constant, or the equilibrium will be lost. An experimental run will soon decide how many lamps must be on in order to arrive at the required conditions.

The Goolden & Trotter governor (shown in Fig. 92) consists of three parts. One is a solenoid, containing a core suspended by a spring. When the governor is made for constant current, the main current is passed through the coil, which has a low resistance, and the core is drawn down into the solenoid against the spring, when

the current is large enough to overpower it, the spring drawing it up again when the current falls below this point. When the apparatus is used for constant E.M.F., the coil has a high resistance, and is placed between the leads, acting in the same way as was explained when the solenoid is used for the main current; since a higher E.M.F. sends more current through the coil, and *vice versa.*

The second part of the governor consists of a switch with many steps arranged in a straight line, connected with resistances, which are placed in the shunt circuit of the dynamo field magnets. The finger of the switch is caused to move in one direction or the other, putting resistance in or out of the shunt, according as the core is drawn into the solenoid, or pulled out of it by its spring, which depends upon the current in the coil falling below, or exceeding, a given amount.

The third portion of this governor is the apparatus necessary to control the movements of the switch according to the position of the core. It consists of a lever, attached to the core, and is worked up and down by it in such a way as to raise, or to permit to fall two bevelled wheels fixed near together upon a tube, through which a vertical shaft passes. The tube carrying the bevelled wheels is so keyed upon the shaft that although free to slip down upon it, yet, when the tube is rotated, the shaft must turn with it. This arbor has upon it a screw which works the finger of the straight line switch up or down, according to the direction in which the arbor is turned. Between the bevelled wheels

mentioned there is rotated by the engine another small bevelled wheel of such a diameter that it may run free between the fixed bevelled wheels: these arrangements are shown in the plate. This rotating wheel has its periphery made of india-rubber, whilst those fixed to the tube upon the arbor are of plain metal. In this way sufficient friction may be obtained between the various wheels at such times as they may come into contact with one another for transmitting motion.

The action may be explained thus: When the charging current becomes too large, and the core is drawn into the solenoid, the lever raises the pair of bevelled wheels, bringing the lower one in contact with the small rotating bevelled wheel, the former being set in motion causes the shaft to turn, whereby the switch-finger is moved and resistance put into the dynamo shunt. When the current falls below the amount desired, the core rising out of the solenoid moves the lever into such a position as to permit the pair of bevelled wheels to fall by gravity; and the upper one then comes in contact with the rotating bevelled wheel, thereby producing the opposite effects, the weight being sufficient to produce the necessary friction. It may be observed that, so long as the charging current is constant, if the adjustments have been properly made, the position of the core is such that its lever supports the pair of bevelled wheels in a manner so as to allow the rotating wheel to run free between them. The setting is effected by varying the strength of the spring. This governor is very sensitive,

and, being strongly made at the same time, it proves highly satisfactory. The diagram shows the apparatus, including the resistance frame, with all connections. With this governor the E.M.F. or the current on the mains can be kept to within 1 per cent. of its normal. In the most recent form of the Goolden and Trotter governor, the bevel wheels are replaced by a screw gear, which is absolutely certain in action, as slipping becomes impossible.

The governor for counter E.M.F. was specially made for the author by Messrs. Woodhouse & Rawson ; and,

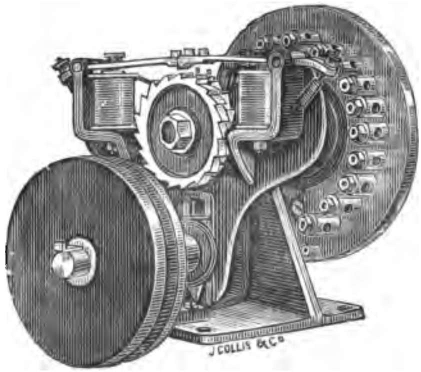


FIG. 93.—COUNTER E.M.F. GOVERNOR. GENERAL VIEW.

after many improvements in the details, it has shown itself most reliable. The movement employed is that of the Porte-Manville governor, but any of the well-known mechanical reversing movements could be employed instead.

Mr. Denny Lane, of Cork, invented a motion identical

with that employed in the Porte-Manville governor many years before this appeared. He devised it for a governor on engines employed with gas exhausters, and it was called by him the "brake and tappet" regulator or duplex governor.

As originally constructed, a part of the governor, to be described, was made to oscillate continuously, by being connected to some part of the engine; and, in order to explain the action, let it be supposed

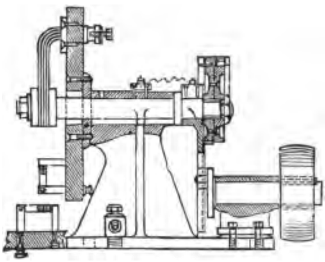


FIG. 94.—COUNTER E.M.F. GOVERNOR. SECTION.

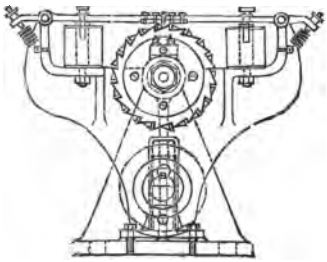


FIG. 95.—COUNTER E.M.F. GOVERNOR. BACK. ELEVATION.

to be so arranged. The oscillations are produced by means of a rotating pulley, which carries mechanical arrangements for translating circular into to-and-fro motion. The oscillating portion carries two magnets, each actuating a pawl, only one acting at a time (see Figs. 93 and 95). When a pawl is drawn down by its magnet, the oscillating motion causes it to rotate a ratchet wheel fixed on the shaft, which carries the finger of the switch; and the arrangement is such that one pawl drawn down causes rotation of the wheel and

shaft, moving the switch finger over the contact pieces in one direction, whilst the other pawl, in action, produces motion the reverse way by engaging with another ratchet wheel, which has its teeth cut in the opposite direction to the first, and also fixed upon the shaft, thus putting

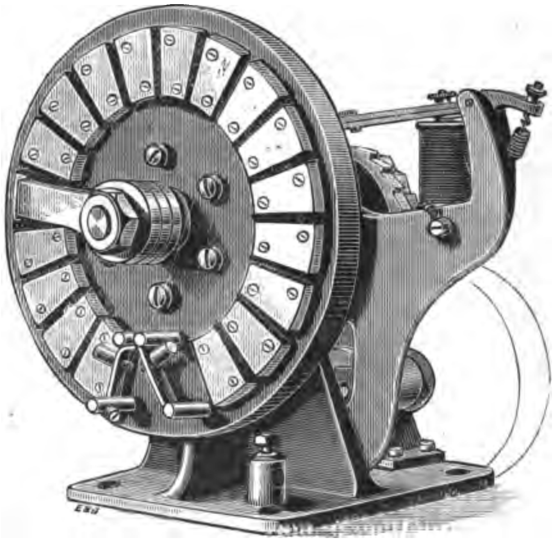


FIG. 96.—COUNTER E.M.F. GOVERNOR. FRONT ELEVATION.

counter E.M.F. cells in or out of one of the house lines, according to which magnet on the oscillating part draws down its pawl. These two magnets receive their currents from any good form of E.M.F. regulator. Such a one as has been described in connection with the automatic switch for charging the cells, answers the purpose well, and is virtually a two-way switch, worked

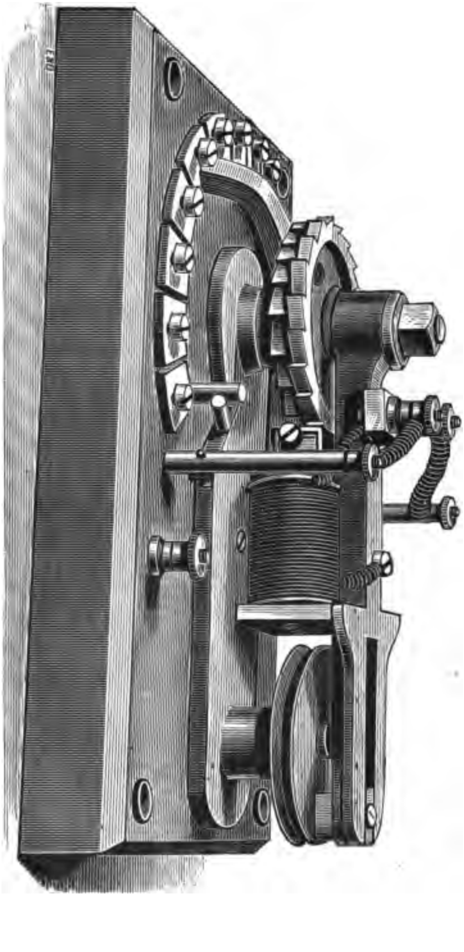


Fig. 97.
Small Governor for Dynamo Shunt.

by E.M.F., so that the current is given to one magnet or the other, according as the E.M.F. is above or below the normal. When the correct E.M.F. is established, the regulator finger swings between its contacts, sending no current to the governor magnets, and neither pawl is drawn down.

Such an apparatus, with slight modifications, can be used as a constant current governor, in which case the high resistance coil upon the E.M.F. repulsion regulator is replaced by a thick wire coil, which carries the charging current. Consequently, the difference between the E.M.F. and current regulator is that one is worked by placing a high resistance coil upon the instrument and placed between the leads, whilst the other has a low resistance coil which carries the main current, and the governor is the same in form in both cases, the size of the switch being the only difference. Figs. 93 to 96 show various views of the governor as arranged for counter E.M.F., the switch being large to carry the main current, and Fig. 97 indicates the modification when used with a dynamo for constant E.M.F. or constant current, with a smaller switch, as it only carries the shunt current.

The following are the improvements which have been added since the blocks, from which these plates have been printed, were made. The author uses storage cells in connection with this apparatus. Therefore, to protect the contacts from injury, the divided finger with a resistance between is employed; and this arrangement is such that a cell may be placed between the

fingers, instead of the resistance, so that a spark can be prevented by means of counter E.M.F., if this is preferred to the use of a resistance. On each of the ratchet wheels a tooth is filed away to avert the possibility of injury to the apparatus, should it continue to work after the finger has reached the end of the contacts. The current is conducted to the coils of the magnets by hinged levers, instead of a flexible wire, neither of which is shown in the plates. The flexible wire was not found to wear well. It may be pointed out that the portion of the apparatus at the lower part of the switch, seen in Fig. 98, is intended to cut the current from the magnet, which may be acting when the finger reaches the last contact. This prevents the apparatus from being over-run. The over-running might happen, notwithstanding, if the adjustment of this part of the apparatus has been badly made, or has been meddled with. In order to make doubly sure against such an accident, the removal of the two teeth above mentioned is resorted to. Hence, should the current to one of the magnets, by any chance, not be cut off, and the governor continues to run, the switch finger will no longer be advanced after reaching the last contact, because the depressed pawl will meet no tooth wherewith to rotate the wheel whose shaft carries the finger, when this has been reached.

To avoid running the apparatus continuously, and to admit of its acting when the engine is at rest, the following device has been added: A magnetic switch is so arranged that, whenever a current passes to either of

the magnets upon the governor, this apparatus acts. The switch starts a small motor, which sets the governor, in motion. Thus, each time a pawl is depressed, the motor starts, and causes the governor to work; but when normal E.M.F. is established, and no current passes to the magnets, the magnetic switch ceases to act, and the motor stops. In fact, this magnetic switch acts as a relay.

In practice, the work done by the counter E.M.F. governor is this. As charging proceeds, cells are put in, one by one, in the course of the day; and on stopping, the majority are taken rapidly out. Those remaining are removed from the circuit, one at a time, at intervals during the evening; and when the cells give a good E.M.F., a few are put in again after the lamps are extinguished, in the course of the night. The motor, therefore, does not run more than a minute a day at most. Such arrangements remove all anxiety, break-downs become practically impossible, and a steady, good light can be obtained at all hours.

Duplicates, clutches, and other complications may be completely dispensed with, excepting in those cases where the installation is very large, and more than one dynamo is required to do the work.

It is possible, when the E.M.F. is just high enough to charge, to construct an apparatus to put the dynamo to the cells, by differential action, *i.e.*, difference in E.M.F. between dynamo and cells. These instruments are very sensitive, and might prove of service in small gas

engine installations; but there is not much to be gained by their use in other cases.

The E.P.S. Co. and other firms make automatic switches, but they are less sensitive than those described.

When the variations in the speed of the engine are very great, say over 10%, and sudden, no governor will meet the difficulty by itself, on account of magnetic momentum. In such cases a very loose belt will often enable the governor to do the work required of it, by means of "slip." If this is insufficient, the dynamo pulley may have a ratchet or roller clutch within it, permitting the armature to run faster than the pulley at any time.

When a constant current is required, a constant current dynamo meets the difficulty, which is only likely to occur when the electric light is driven by an engine running machinery direct, without motors, at the same time.

CHAPTER VI.

ALTERNATING CURRENTS.

So far, alternating currents have not been dealt with in this work, because they are not applicable for charging an accumulator, unless they are converted first into direct currents, which process is termed redressing. For carrying this out, there is, at present, no method sufficiently reliable and convenient. The subject to be treated in this chapter would, therefore, appear foreign to the scope of the book; and this is true. It has been added to assist those who, already possessing electric light in their country houses, find themselves in great discomfort when living in their town abodes, supplied only with the ordinary sources of illumination, and are, therefore, tempted to obtain a current from a public supply company. At the present moment, alternating currents are largely used for public supply, for reasons to be stated later. In consequence, it has been thought that a few words on this subject would be welcome, so that this work may be consulted in reference to town as well as country installations under the circumstances just described. It may be assumed that, with few exceptions, private installations employ direct current, since this is less dangerous and easier to produce

than the alternating current, and is likewise applicable to motors. It is not proposed to enter fully into this subject, especially as a large volume would contain no adequate description. The matter will only be treated to such an extent as may be serviceable to the user of the alternating current system.

If a complete view of this subject is desired, Dr. Oliver Lodge's work entitled, "Modern Views of Electricity," and Dr. Fleming's "The Alternate Current Transformer," should be consulted.

In the case of a direct current the pressure is all in one direction, but with an alternating current the pressure is first in one and then in the opposite direction, these alternate changes in the direction of the pressure being extremely rapid. From these considerations it may be inferred that, if a 100-volt alternating current be used, and observed by the sense of touch, the shock will be equal to that given by a 200-volt direct current, because the successive changes of pressure from one direction to the other are so rapid as to be unnoticed by the brain, since this organ only receives the impression $\frac{1}{8}$ second after the event, and the sensation is that produced by the sum of a 100-volt pressure on the opposite side of a neutral point. It must therefore be concluded that, when alternating currents are employed, they should be regarded as if of double their given pressure in respect to their influence on living bodies.

All instruments cannot be employed with these currents, and those must be excluded which contain permanent magnets, on account of the innumerable

reversals, which would rapidly demagnetize the steel. Also, all iron that may be employed in connection with alternating current apparatus must be very soft, laminated and ventilated, and the instruments have to be specially calibrated. Where subdivision of the iron is not possible, the pieces must be very small and the metal soft. The effect of the successive reversals of magnetism in iron causes it to heat, and this phenomenon is termed hysteresis. The effect of lamination is to interrupt eddy currents, which are produced in the iron and increase its temperature. Such currents are often termed Foucault currents. Since the object to be attained by the alternating current apparatus is not to heat the iron it may contain, all energy consumed by the conversion of electrical energy into heat is a waste of power; and every effort, in designing, is made to reduce these heating effects to a minimum. It might be supposed that the needles of the voltmeters would swing to and fro when employed with such currents, but the rapidity of the alternations is so great that no time is permitted, between each wave of opposite pressure, for the working portions of the instrument to change the positions they may have assumed. For the same reason incandescent lamps do not alter their brilliancy, insufficient time elapsing for the filament to cool between the successive impulses. Besides, an impression upon the retina of the eye lasts $\frac{1}{8}$ second.

The only apparatus that interests the consumer is the transformer, since it is usual at the present time to place one for every house. A transformer is

sometimes termed converter and secondary-generator. This apparatus consists, in its most elementary form, of a core of iron, laminated, for the reasons above given, which has wound around it two independent coils of wire, one having a high and the other a low resistance. The ends of the low resistance coil are connected with the mains going to the house. The ends of the high resistance coil are connected to the primary mains, which carry the current from the public installation. The transformers for the different houses are placed in parallel upon the primary circuit. The house circuit, consequently, is quite distinct from the primary circuit. The only connection existing between the two is that each has a coil, in the course of their circuits, placed close together, in which a piece of iron (common to both) is inserted. In fact, a transformer is nothing more than an ordinary form of induction coil. There are numerous modifications of such apparatus in the market, but they are all constructed upon the same lines, the objects aimed at being efficiency, good regulation, and absence of heating.

The Mordey transformer is shown in Fig. 98.

Two forms are here shown, one intended to fix to a wall vertically, and the other to stand on the ground. The diameters of the wire employed upon the coils in all cases must be made of sufficient area to carry the current, which they may be intended to pass.

The results produced by a transformer are extremely remarkable. If the various parts of the apparatus have been suitably proportioned, a current of high

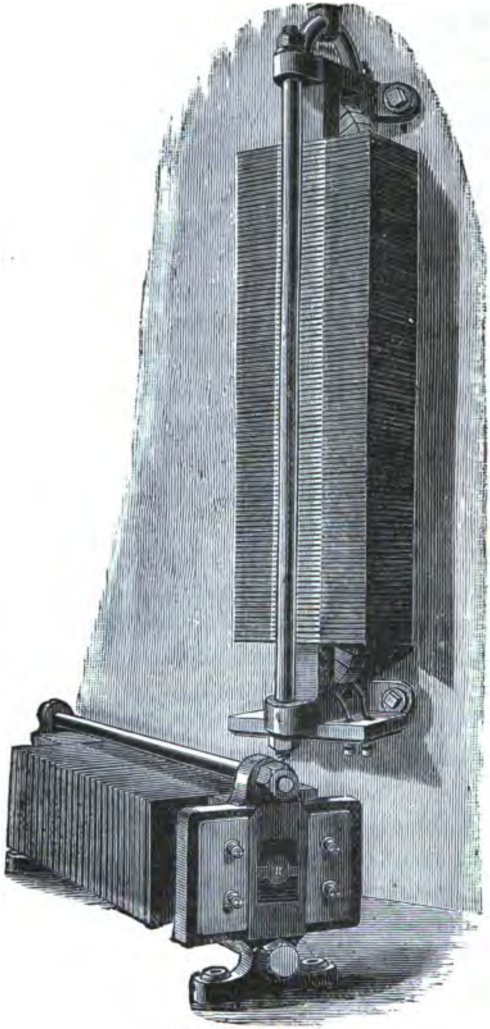


FIG. 98.—MORDEY TRANSFORMERS.

E.M.F., passing through the high resistance coil, will set up a low E.M.F. in the low resistance coil, enabling a current to pass through this circuit, which is in connection with the house, proportional to the resistance which it may contain. And only so much current will be drawn from the primary mains, through the transformer, as will be necessary to supply the energy required upon the house circuit. The volt × ampères taken from the primary circuit on the transformer being equal to those used on the secondary. There is, of course, a slight loss in the conversion; so that the whole of the energy in the primary coil is not converted for useful work.

It may be observed that the current which passes the primary coil is proportional to that passing through the secondary one. Hence, if the apparatus were perfect, when the house is using no current, the primary coil should likewise pass no current. This result is produced in consequence of the self-induction the apparatus possesses, and which acts like counter E.M.F.; and the phenomenon is called "impedance." Direct currents give the phenomenon of impedance, but it is momentary. The continual rapid reversals of the alternating current renders this circumstance not only apparent, but an important factor in its mode of working results.

It is evident that, should by any chance the primary and secondary circuits upon the transformer come in contact with one another, by wear of the insulation or the destruction of any part or even the whole of

it, through over-heating, by accident or otherwise, the high E.M.F. on the primary lines would be given to the house. Hence the necessity for thoroughly protecting all parts in connection with the circuit upon the premises liable to be touched.

Equally desirable it is that the transformer should be kept in a fireproof, dry, and well-ventilated place, and never be touched without turning off from it the primary current by the D.P. switch, which is always placed close by.

It is practically impossible to maintain perfect insulation on the high pressure primary circuit, which is equivalent to saying that either one or both mains are in partial contact with the earth. Consequently, if a person were to touch one of these conductors, or any apparatus directly connected with them, the part touched would then be placed in connection with the earth through his body, unless he happened to be standing upon an insulating substance. And as this is, generally, not the case, by this action of touching, when both mains, or when the main opposite to that which is being touched, have bad insulation, he completes the circuit to earth, and an amount of current will pass through his body proportional to the resistance between the mains and the earth, which would injure him considerably, or even fatally. When on circuit to mains it may be remarked that, when a shock is felt on touching a main, the faulty insulation which produces the result is not upon the main touched, but upon the opposite one, and to ascertain whether the main examined

was faulty, the opposite one must be felt. A faulty insulation might be observed when existing upon the main touched, provided a very considerable resistance existed between the point in contact with the hand and the place where faulty insulation existed; but this would be extremely rare, because conductors are usually made so that their whole length shall have but a very small resistance. Naturally, in the place of experimental testing for faults, by means of the sense of feeling which would, in many cases, prove fatal, instruments are employed. The resistance of the body varies with the state of the skin, and it is higher when the skin is dry. When moistened with acid, the skin is very sensitive to electrical action, and when alkaline much less so. This is the chief reason why some persons can bear the application of higher E.M.F. than others.

Transformers generally produce a buzzing sound when current is passing through their coils.

There is a possibility of dangerous high pressure existing in a house without any indication being given of its presence; and fatal results might ensue, if any part carrying current were touched. The conditions might be these. The insulation of the house circuit might be perfect, the two circuits in the transformer in contact one with the other, and one of the primary mains have a leakage. Under such conditions, one primary main is in electrical connection with the house circuit, but, since the other primary conductor is supposed to have good insulation, no high pressure *current* can pass through the house, inasmuch as

the return circuit is not complete and the house pressure will be normal, as usual. But if, in the house, a main is faulty, the high pressure in connection with the secondary system now makes itself evident. The very fact of a person touching any portions of the conductors so situated would give this earth, and might suffer death in consequence.

The necessity for provision against touching any metal carrying current, situated in houses, is, therefore, important; for there is no guarantee against the combination of circumstances just mentioned taking place. Sooner or later the primary and secondary coils in the transformer will short-circuit, as these apparatus are now made. And, although, if an earth, good or bad, were given to a house main through a person's body, under the conditions already stated, a fuse were to go, death would very likely have supervened before the current was cut. There is only one certain way in which this danger can be obviated, and that is by placing metal plates in contact with earth between the primary and secondary coils on the transformer, so that no contact could arise between these two circuits without touching the earth-plate first. Consequently, if the insulation on the primary circuit should become injured, it would be put to earth; and that would destroy the primary fuses. The inmates would, therefore, save risking their lives at the inconvenience of darkness till the necessary repairs were made. Another method of protecting life is to earth one main, but this has hitherto encountered strong opposition on the part of insurance

and supply companies, which would lead one to suppose that they looked more to dividends than to the lives of their customers and workmen. Major Cardew and Mr. Hedges have each devised safety arrangements, but they are delicate, and death might ensue during their action, so that life should not be made dependent on these or any other sensitive devices. So many deaths have been caused by the use of high pressure current that attention has, at last, been given to this point; and the large mains, which are to supply current to certain portions of London from the big installation in the course of construction at Deptford, will have one conductor placed to earth in order to render the primary system safe. The currents in these mains will have a pressure of 10,000 volts, and it consists of two concentric copper tubes insulated from one another, the outer one being placed to earth; inasmuch as its resistance is very low and no access can be obtained to the inner conductor, the danger to life is eliminated. The object of using tube in the place of solid core is that high tension currents tend to travel near the surface of the conductor, so that the central portion would carry but little current. Faraday was probably the first to show this phenomenon for static electricity and Sir William Thomson has proved it for alternating currents, but the reasons are not the same as in the case of static electricity. The cable was designed by Mr. Ferranti. It must be borne in mind that the stress in the substance of any conductor is but small. The strain is in the insulation surrounding it, be this an

insulating material or the air. Sir W. Thomson and others have now proved that the energy of the current travels through the dielectric (insulation) and the conductor acts simply as a director. Hence the current enters the conductor from the outside surface. If the alternations are very rapid, no time is permitted for the current to penetrate far into the conductor, and, consequently, only the outer shell is used to convey the current. Hence also the resistance of the conductor will vary with the speed of the alternations, since the useful area of the wire varies with this speed. The insulation may be compared to a steam-pipe, which bears the pressure of the steam and consequently is under great strain, but there is no true analogy. It will, therefore, be a question to be decided in the future, how long the various insulations now in existence will last, when placed under great stresses. Many laboratory experiments have been made for ascertaining the life of the material. But common sense would seem to indicate from experience in other matters that the conclusions, derived from such experiments, are not final unless time enters as a factor. Copper itself undergoes a change by the passage of the current. Its atoms are in continual motion when in the condition termed electric, and, after a time, it assumes a crystalline form rendering it brittle; and its resistance, when in this condition, no doubt would be increased. Consequently, not only the time, over which the insulation may be expected to last, is a matter of uncertainty; but the copper conductors themselves may be perishable.

The alternations (complete cycles) in the mains of the London Electric Light Supply Corporation are 80 per second in their present Grosvenor Gallery installation. The Deptford works, now on the eve of starting, are going to employ 68.

Sir William Thomson and others have shown that the ordinary methods of measuring the resistance of leads has no value for alternating currents, since they set up a spurious resistance which varies with the number of alternations per second. This might easily be imaged and predicted before experimenting to verify the circumstance.

If a leakage were to exist in the house mains, when all lamps and apparatus are turned off, there would be due to this cause a continual leakage from the primary mains through the transformer, and probably the leakage in the secondary circuit would be so small that the house meter would not register it. If such leakages existed in a great number of houses, not only would the supply company suffer pecuniary loss, but a large amount of power, beyond that required to light the district, would be required to supply this waste. For this reason, supply companies refuse to connect their systems with any house, unless the insulation within it is proved to be satisfactory and in accordance with their standards. The refusal to supply any house, in consequence of undue leakage, may appear a hardship to the owner; but, in reality, it is to his advantage, because bad insulation is a source of danger, and he, therefore, becomes apprised of its existence and is obliged to remove it

before obtaining the current. It must also be remembered that the possibility of a fire in the houses adjoining, due to bad wiring and fittings, is likewise averted by this system of compulsory testing.

To give an idea of how, in practice, the transformer acts, suppose the E.M.F. of the primary circuit is 2,400 volts (as upon the lines of the London Electric Light Supply Corporation), and the house has to be supplied with 60 ampères at 100 volts, *i.e.*, a current for 100 16-c.p. lamps, then, when all these are in use, only 2·5 ampères of the primary current would be required to produce these 60 ampères in a secondary circuit.

This example brings to the mind very clearly why currents, having high E.M.F., are employed for public supply, a very small conductor being able to carry an enormous amount of energy. Were it necessary to carry the low tension current from the works to the houses without great waste in the conductors, the latter would be of a size so enormous as to place universal electric lighting far beyond the bounds of possibility. The waste in the leads is proportional to the square of the current. Therefore, if the current is doubled, the leads would have to be four times the section, in order that the waste should remain the same, three times the current nine times the section, and so on. To give a practical idea of the difference of waste, that is to say, fall of E.M.F., in a low pressure and high pressure system the following figures may be considered.

Let a central installation supply a thousand lights, in the one case giving 100 volts and in the other 1,000,

which has to be reduced to 100 at the houses. In the 100-volt system the total resistance would be $\frac{1}{8}$th of an ohm, and, if the conductors leading to the houses have a resistance of $\frac{1}{12}$th of an ohm, half the pressure would be absorbed by the mains. Consequently, since the pressure at each house is to be 100 volts, the E.M.F. at the supply works would have to be 200 volts; in other words, the waste would be 50 per cent. And, if the remarks made in an earlier chapter upon the parallel system be considered, it will be noticed how difficult it would be to give equal pressures at every house. In the case of the 1,000-volt current, 60 ampères would be required to supply a thousand 100-volt lamps. The loss in this case, supposing the same cables were employed as before, would be one-sixteenth of that amount, *i.e.*, $\frac{1}{17}$th of the total energy; so that, to ensure 1,000 volts at each house transformer, the pressure of the current at starting need only be 1,059 volts. It is also evident that the variations in the pressure at the points of delivery, at every house, must fall far within the limits of 1,000 and 1,059 volts, and, consequently, the pressure of the supply current at the various houses would be practically the same, and no variation would exceed, say, 6 per cent.

Alternating current dynamos cannot excite their own magnets, but require a small continuous current machine, which is termed an "exciter" when used for this purpose. To give an idea of how the alternating current is produced, a very common form of machine may be described. A large number of electro-magnets are placed upon two circular frames in such a manner that, if a frame were

laid flat on the ground, the magnets would all stand upright, something like a crown. These two crowns of magnets are placed vertically, their free poles facing one another, with a small space intervening between them. When a current, from the exciter, passes through the coils of all these electro-magnets, which form one circuit, those magnets which face one another have the same polarity. But the free poles of the successive magnets are alternately N. and S. In the space between the poles of the magnets upon the opposite crowns there revolves a wheel which carries on its periphery a large number of coils placed in one circuit called the armature, which may, or may not, contain iron cores, and their coils are so situated that they pass in front of the magnet poles with their cores facing the poles. The result is that, when the magnets are excited, and the wheel is turned, causing the coils to pass their poles, a current alternating in nature is produced by induction in these coils. Since all the moving coils are in one circuit, the circulating wire upon the armature has only two free ends, which are brought to two insulated copper rings placed concentrically on the shaft of the turning wheel. Upon these, two brushes rub, and collect the current. Consequently the sectioned commutator, employed with continuous current dynamos, is replaced by two complete metallic rings, which are a small distance apart, side by side. Continuous current machines are really alternating in nature, but many points of the armature coil are severally connected with the plates on the commutator, and the collection of the current is made from this by means of

brushes, the whole system being such as to dress the alternating current into a direct one. There is no difficulty in working direct current dynamos in parallel, and, although this may be done with alternating current machines, many difficulties have been experienced in this respect. Mr. Mordey has recently shown the conditions required for working these machines in parallel, so that one of their disadvantages has been overcome. Alternating currents can work the ordinary form of motor, but only with great inefficiency; and the magnets in this case would have to be laminated to prevent heating. Mr. Mordey has also shown that an alternating current motor is possible, using the ordinary form of alternator for this purpose; but it is necessary to start it with a motor and direct current. Messrs. Siemens have also shown the reversible property of alternators. Many motors have recently been put forward, which are said to work with alternating currents; but, apparently, the success has not been complete. There is little doubt that before another year has passed the problem will have been satisfactorily solved.

When it is desired to restrict the current or to lower E.M.F., resistances are generally employed in the same way as in the case of direct currents. But another method for accomplishing the same thing is by employing impedance or choking coils. Such an apparatus consists of a coil of wire containing a core of laminated iron, which acts as a retarder, and is equivalent to the insertion of a resistance or counter E.M.F. in the circuit. Even if one main, carrying an alternating current, is

passed through an iron pipe, the current is impeded; but if both conductors are taken through the iron tube, the impedance is neutralized. If, in the first case, the tube had been made of any non-magnetic metal, and its circuit completed, an E.M.F. would be set up in it; which would not be the case when both mains are placed together in the tube. These observations have an important bearing in laying cables in installations supplied by alternating currents, indicating arrangements which should be avoided.

When the current is not delivered at a uniform pressure the inmates of a house are placed at considerable inconvenience, since the light given by the lamps is sometimes very bright, and at other times very dull. Under ordinary circumstances, there is no power to remedy this drawback, except by communicating with the supply works, which may not be possible; and, even if done, they may, for some reason or other, be unable to meet the complaint. Any apparatus, therefore, placed in the house, to enable the pressure of the current to be raised or lowered at will, would be found most welcome. Mr. Gisbert Kapp has devised a special form of apparatus intended to be employed at the supply works for maintaining constant pressure; and this, when made on a smaller scale, effects the same results when placed for service in individual houses. The author has one in his London installation, and he finds it indispensable. A complete description of how it is made and how it is worked will be given. This apparatus is shown in Fig. 99 (from *Industries*, April 12, 1889).

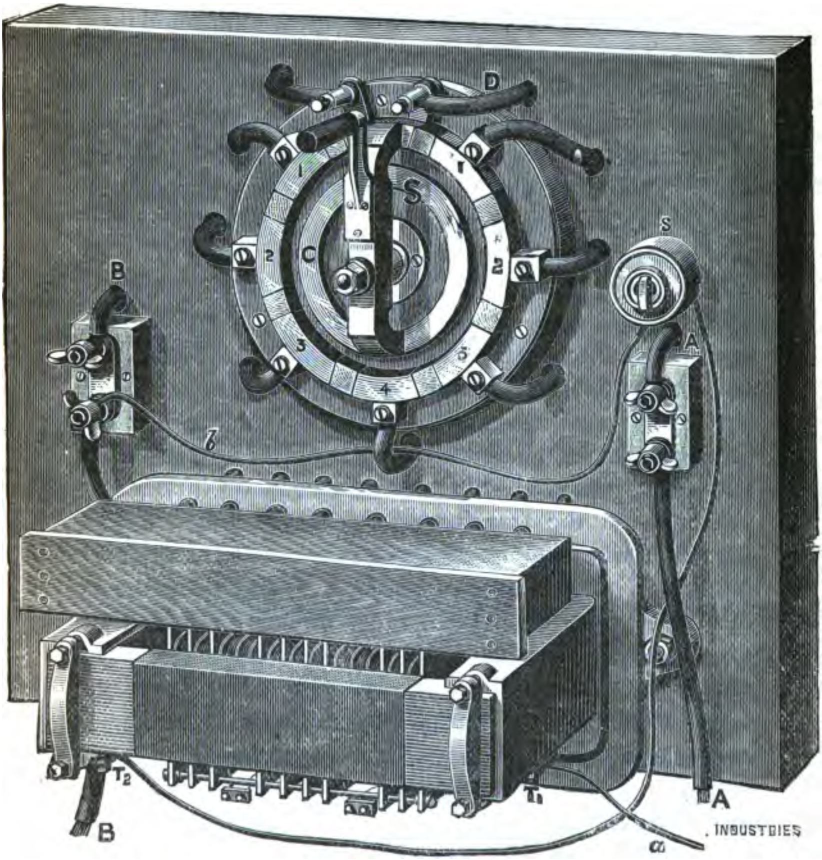


FIG. 99

KAPP'S REGULATING TRANSFORMER

This apparatus consists of a transformer, which is in connection with the secondary circuit, the thick coil upon it being placed in the course of one of the leads. The current enters the apparatus by the cable BB, which comes from the secondary circuit upon the primary transformer. This cable is attached to the contact ring C upon the switch S. It then passes through the finger and onwards to the thick wire coil upon the regulating transformer, leaving the apparatus by the cable D A A, which passes to the distribution board or elsewhere. The thick wire coil upon the regulating transformer is divided into sections; and these are in connection with the contacts of the switch S, which enables the current to be sent through one or more of these sections which, as already mentioned, are in series with one main. These sections are all joined together upon the transformer so as to form one coil. The fine wire coil upon this transformer has a high resistance, and is placed across the mains by means of the wires *a b*, which are attached at T_1 T_2. One of these wires has a switch in its course, *s*. The results are that, for every section of the thick wire coil introduced into the circuit of the house-conductor in connection with it, the E.M.F. on the mains is raised 2 volts; and since there are five subdivisions of the coil used for this purpose, the pressure can, by successively moving the switch finger over the corresponding five contacts marked 1 to 5 on S, be increased up to 10 volts by 2-volt jumps. There are yet two more sections of the thick wire coil in connection with contacts 1 and 2

(right-hand side) upon the switch, and on these the switch finger can only be placed after passing its zero position, since there is a stop-piece between contacts 5 and 2. The arrangements are such that, when the current is permitted to pass through these two sections of the coil, its direction is in the reverse way to that when it passes through the other ones mentioned. Consequently, instead of a rise of 2 volts per step, there will be an equivalent fall in the pressure. In this manner, if the E.M.F. on the house mains should rise too high, it may be lowered. Since the drawing was made, the switches S, *s* have been replaced by one switch specially designed by the author. Its description is as follows. The switch finger is divided with a small resistance placed between each half, enabling the shifts to be made without cutting off the light or burning the contacts.

There is also a special form of snap-action to ensure the finger assuming its proper position. Combined with this switch is a second one, and so arranged that, when the main current is turned off from the transformer, the thin wire circuit is cut at the same time, and a small waste of current, which would pass at such times, amounting to nearly two ampères, is in that way prevented. The practical result of the apparatus is that it can convert ampères into volts. When employed for reducing pressure, it consumes a certain amount of power also. This may appear a paradox. But it must be remembered that, when the pressure of the house current is lowered, a less amount of current passes through

every lamp; and, theoretically, the whole of the saving should be found from this result. Under no circumstances or conditions can a transformer produce strictly theoretical results, for there are losses of energy, though not very great, in this apparatus, as in all other machines. There is another small automatic apparatus in connection with this transformer, which breaks the thin wire circuit in the event of the pressure on the house-mains circuit rising beyond 100 volts. This cut-out consists of a solenoid which draws into its centre an iron core which is balanced by a spring. This core discharges a switch at the proper time. By means of this automatic instrument the lamps at times are saved, *i.e.*, if the pressure had been raised 6 volts and the E.M.F. on the secondary mains were to rise, say, to 98 volts, the lamps would be worked at 104 volts, which would injure or break them. But the fine wire circuit would be cut at the moment that 100 volts were reached, destroying the action of the regulating transformer and averting the injury, since the current passing through the thick wire upon this transformer does not raise its pressure, excepting at those times when a current is passing the fine-wire circuit.

The remarkable properties of transformers come into play in this particular instrument as it does on other occasions, *i.e.*, the current through the fine wire increases in proportion to the increase of current in the thick wire. This regulating transformer could only be used in connection with alternating currents, and analogically replaces the counter E.M.F. governor employed with direct

currents. Such a regulating transformer, with an ordinary kind of switch, costs about £25; but, with the improved switch and automatic arrangement, about £10 more should be added to the cost. The price is mentioned in order to give information to such persons as may be on alternating current circuits and desire to test the great convenience this instrument offers. The insertion of such an apparatus is not unfair to the supply company, because the extra current consumed is measured upon the meter, when there is one; and, when this is absent, the consumer is only obtaining the pressure at his lamps for which he contracted. When the measurement is by meter, the supply company ought to allow a reduction in the payments for current produced below normal E.M.F., because the current used in this transformer is simply that which would be necessary to give the pressure which should have been supplied. A meter in the course of the fine wire circuit would measure the deficiency. The arrangement presents another advantage, which is of importance even when a regular and standard pressure is given. At those times when a more brilliant light is required this may be done; and, on other occasions, the pressure may be somewhat lowered. In this way the lamps may be given a much longer life, without the disadvantage of obtaining this end by inserting lamps of higher volts throughout the installation, which would not produce as good a light as if the proper voltage lamps had been used, and is an inefficient proceeding. Also the wiring in the house may be of a smaller section, and this saving in cost would in many cases more than

cover the expense of the apparatus, and without increasing fire risks.

The distribution of electrical energy by means of direct current is not so simple as with alternating current, the apparatus for this purpose being more complex than the transformer. Reduction in the pressure of direct currents may be effected by means of storage cells, voltmeters, and motors, sometimes called "direct current transformers"; these three methods being equivalent to an extended 3-wire system. The chief disadvantage attending the use of alternating current is that no storage system exists in connection with it, in the present state of knowledge. Many public installations have been recently started, using direct current combined with accumulators. A few years must elapse before the vexed question is settled, as to the comparative merits of the two systems of alternating currents and direct currents; also as to whether both systems may not, under special given conditions, be employed with advantage.

CHAPTER VII.

TESTING.

WHEN the wiring of a house is completed, and even during its progress, the conductors have to be tested for insulation. Every fitting and every piece of apparatus intended to be used must also be tested. The accumulation of a great number of faults, apparently insignificant when taken by themselves, will show a large leakage on the system. Too much care, therefore, cannot be taken in avoiding the use of fittings which give the slightest indication of leakage. As no substance is a perfect non-conductor, it becomes impossible to construct any fitting which shall have no leakage whatever. The presence of moisture in the air assists this result, especially as parts having opposite polarities are brought close together in many of the fittings. The consequence is that the more lamps there are in an installation, the greater will be the leakage indicated upon the system. Hence it is impossible to lay down that an installation shall have one standard of resistance and no other.

The greater the number of fittings in a house, the

less will be the total resistance of the installation. In the rules for the prevention of fire risks, issued by the Institution of Electrical Engineers, it is stated that the leakage should not exceed $\frac{1}{5000}$th part of the total current intended to be used in the installation when tested with a current having an E.M.F. equal to that intended for service on the system. However, if a better insulation can be obtained, it should be secured. The proper method is to make the insulation tests by means of a Wheatstone bridge. But to use this properly requires a special knowledge, and the instrument is expensive. A simple way, which can be employed by most persons having an elementary knowledge of electricity, is to take the measurement by the deflection method. The values of the deflections are ascertained by the makers of the instrument, which is a galvanometer, and are supplied with it to the purchaser.

The best form of such an apparatus consists of a high resistance galvanometer of the Post Office pattern, and a few portable Leclanché cells, the whole contained in a box which can easily be carried. The case has two terminals on its outside for attaching the wires. The majority of these apparatus now in use have been made by the Indiarubber, Gutta Percha, and Telegraph Works Company, of Silvertown.

Every fitting, which has upon it metallic parts of opposite polarities, must be tested with this instrument, in order to ascertain whether any current traverses its insulating portion. If the galvanometer needle does not move, the fitting may be passed. The same process should

be gone through with lamp pendants, brackets, and electroliers, to see whether any deflection takes place, on connecting each lead successively to the metallic parts of these fittings through the galvanometer, taking care that the contact is not made where lacquer exists. Switch and fuse-boards, switches, cut-outs, ceiling plates, connector plugs, and all other apparatus should be tested in a similar manner with a view to learn whether there is any leakage in those parts which ought to be non-conductors.

The wiring may have two kinds of leakage. One may take place between the two leads, and the other between one or both leads and earth. In order to test them for the first case, the wires from the testing instrument are attached one to each lead. If no deflection occurs, they are in good order in this respect. To test for earth one wire from the galvanometer is connected to each lead successively, and the other wire is attached to a water or a gas-pipe, preferably by means of a solder, when again no deflection will take place, if the insulation is good. If, when testing for "earth" all the fittings and other apparatus being placed in the circuit, no deflection occurs, the insulation may be regarded as perfect. If deflection does occur, the number of degrees must be noted, and the makers' table referred to, which was furnished with the instrument. It must be seen whether, from the number of lamps installed, the leakage is in excess of that which would be permissible, the margin allowed being greater as the number of lamps is larger. Should the insulation be below the mark, the faulty place or

places must be sought for by disconnecting various portions of the system and testing them separately. When the system is tested for earth, the lamps should be turned on; but, when tested for short circuit, the lamps must be turned off, or, better still, their switches left turned on and the lamps removed from their holders; since in the latter case the lamp leads and fittings will be included in the test. Also any apparatus, usually placed between the leads, must be put out of the circuit by a switch or otherwise. To give an idea of the manner in which the deflections are made to indicate desired results, let it be supposed that, when a test is taken over the whole installation, the result is that the needle does not move, then everything is perfectly satisfactory, and, if twenty lamps are employed upon the circuit, a worse result must not be shown. For 100 lamps a deflection of 5 degrees might be permitted, and for 200 lamps perhaps 15; but the actual value of the readings will naturally depend on the sensibility of the galvanometer and the number of cells employed for the test. If a more sensitive instrument is required than the ordinary form supplied from the Silvertown works, it may be obtained by possessing one of Messrs. Elliott's first-class Post Office galvanometers.

When the house is supplied by a public company, it is well to ascertain the insulation tests they may require, and note the corresponding deflections on the galvanometer with which the tests are to be made.

It is frequently necessary to test an installation by observing the behaviour of the machinery and apparatus,

when the number of lamps in use is varied. It is evident that varying the number of lamps is equivalent to varying the resistance of the dynamo outside circuit. The more lamps lighted the lower this resistance. Consequently, if the house mains are connected to a variable resistance, suitably divided, all the effects, which would be produced upon the machinery by giving current to one or more lamps up to the maximum number, may be obtained. When a resistance is employed to produce equivalent effects, it is termed an artificial resistance; and, if such an apparatus is placed in the dynamo room, the behaviour of the installation may be tested and examined at any time without the necessity of turning on and off the lamps, motors, and so forth in the house. Artificial resistances consist of ordinary resistance frames suitably divided to obtain the steps required, and the section of the wire is so chosen as to carry the current without overheating. Wire of a very small section may be employed, if the frame be placed in a water tank; and one convenient form of making an artificial resistance is to attach the mains to two plates of metal, which are put in a vessel containing water, the latter acting as the resistance, the variations in resistance being made by moving one of the plates nearer or further from the other. When the liquid resistance is required to be low, a dilute solution of one part sulphuric acid to 9 or more parts water may be employed in the place of water.

CHAPTER VIII.

ESTIMATES.

IT is almost impossible to give more than a very general idea of the cost of electric light installations, because the conditions under which they are erected differ to so great an extent. However, in order to guide those who are seeking information on the subject, a carefully compiled table has been prepared. This, together with the necessary explanations for understanding the basis on which the results have been obtained, forms the whole of the chapter.

Unless electrical work be thoroughly well done, and passed by competent persons other than the fire-office inspectors, who have often not sufficient practice to understand every detail thoroughly, the result will not be satisfactory. In all cases, however, the fire office must receive a notice of the intention of the insurer to light by electricity; and it is well to ascertain if any special requirements have to be attended to before starting the work, as after-expense and trouble might thus be saved. If all be properly carried out, there is not the remotest danger of fire, but when inferior work

is done, or the installation badly planned, an absolute danger will be introduced into the house. In the following estimates there has been an allowance of 25 to 50 per cent. margin of power; and this is not considered too much in practice, for the machinery and other portions of the installation are not strained, and in most instances extra lamps are added at future times.

The price of gas is reckoned at 3s. 6d. per 1,000 cubic feet; and coal at 20s. a ton. Each ind. h. p. of the gas engine is supposed to require 20 c. ft. of gas per hour, and each ind. h. p. of a steam engine (with fairly economical boilers), 6 lb. of coal per hour. The working expenses are not increased by the use of an accumulator, because, although there is a loss by their use on one hand, there is a saving in other ways; but under the head of sinking fund and interest an addition is made. The lamps are supposed to be the 16 c.p. requiring 60 watts, and, if 8 c.p. are used, the numbers for the lamps may be doubled. In passages, and places where much light is not needed, the smaller lamps suffice. The 16 c.p. lamps give nearly 20 candles. A gas burner, giving the same light, requires at least 6 c. ft. of gas per hour, and costs £2 2s. a year, on the assumptions laid down in the table for 2,000 hours per year. To this must be added the damage caused by the use of gas at the rate of 2s. per burner, interest and sinking-fund on fittings and piping, together with candles and oil (inseparable where gas is used) at 3s. per burner, making in all, for single and grouped burners, £2 7s. per light a year, when the gas is drawn from a public

supply; but other expenses must be added for private works, such as interest and sinking-fund. In these cases the cost of the gas itself will probably be more.

When gas is used, the consumption of oil and candle is always considerable, lamps being generally used in all sitting and bed rooms. To most people gas is intolerable in sitting and bedrooms, and even when the fumes are carried away—a matter difficult to accomplish—the bulk of the heat remains. Candles and lamps are also largely used for portable light in houses where no electricity is employed.

To the mechanic or the poor man, gas has every advantage. He has no decorations to destroy. It is in the short days that he requires the light most, and the heat is then welcome. Such a man is accustomed to close workshops, and the gassy atmosphere to him is probably purer than that in which he does his daily work. The chief advantage of electricity for this class, especially to those who do piece-work, would be the possibility of employing its properties for motive power in their homes, renting motors for this purpose.

Professor Crookes once made a significant remark to the author. He said that had the electric light been universal at the present day, how wonderful would the invention of candles be thought, if suddenly introduced, thus enabling any person readily to obtain light in its simplest and most portable form, and without the use of cumbrous machinery, or the necessity of attaching the lamp to any fixed point by means of wires before it could be lighted!

The question is sometimes asked, Is more light given by gas burnt in the usual way, *i.e.*, through gas burners, than in a gas engine employed for producing electric light? A gas engine requires about 20 c. ft. of gas an hour per ind. h. p., which, in a properly designed installation, should give current for at least eight 16 c.p. glow lamps. Consequently, for every 20 ft. of gas burnt in the engine, there is produced a light equivalent to 130 or more candles; since a 16 c. p. lamp gives rather more light than its nominal power. A gas burner, made to pass 6 ft. of gas at normal pressure (9-10ths inch of water) per hour, gives about the same light as a 16 c. p. lamp. Hence 20 c. ft. of gas burnt in this manner will produce a light of about 55 candles. It is, therefore, evident that, when gas is employed to produce the electric light, the result is at least 2·3 times better than when it is burned in the usual way. The above remarks are made on the assumption that the quality of the gas is equal to that supplied in London, and, in speaking of candle power, "standard candles" are implied. The light of a standard candle is about the same as that given from a No. 4 sperm candle, which is used in most houses.

In specially constructed gas burners, such as Siemens', the Wenham, the Cromartie, and others, far more light may be obtained from gas than in the common form of burner; but these special lamps, which are constructed on the regenerative principle, cannot be used universally on account of their size and expense. When, however, gas is burnt in this class of illuminating apparatus, there

is no choice as to the light-giving power of gas in the two cases under consideration.

It must be pointed out that, when a gas engine is employed for the arc light, the economy is vastly in favour of the electric light. For one break h. p. a light will be produced of about 2,000 candles, and the results are better per h.p. as the power is increased.

Recent large gas engines require but 17 c.f. of gas per break horse-power.

Electricity can be employed for heating purposes, by permitting coils of wire, or any other suitable apparatus to absorb electric energy, the result being production of heat. But the cost of the production of electrical current at the present day is an effectual bar to its use for such purposes. Where water power cannot be obtained the cheapest power is steam; and, in the best form of engine, not more than ten per cent. of the energy contained in coal can be converted into useful power. The loss during the successive conversions from steam power into electricity, and again from electricity into heat, together with the passage of the current through the mains, is probably not less than fifty per cent. Consequently, five per cent., or very little more, of the energy contained in the coal is converted to a useful purpose. The ordinary domestic open fire is regarded as the most wasteful way of burning coal. Even those who are most opposed to this method of warming, do not consider that the waste exceeds fifty per cent. This extravagant plan for the extraction of heat from coal is, therefore, ten times more economical than by

producing the heat from it by electrical conversion. It must not be forgotten that, with the open fire, two kinds of heat are produced ; the one being the ordinary form, such as that given by a closed stove, and the other by radiation through the air without sensibly raising its temperature. This may be easily observed by any one, standing at a distance from the fire. The heat experienced is found to be considerably greater than the temperature of the room. The late Sir Wm. Siemens always pointed out this peculiar advantage derived from burning coal in open grates.

There is one point connected with gas engines which most people overlook, and it is a very important one :—The fuel is carried to the spot free of expense and without trouble at all times and in all weathers.

In the consideration of an accumulator it is assumed in every case that never more than 75 to 80 lamps can be lighted at one time from this source alone, though the installation may be for more lamps; because it is rare that a larger call is demanded when the machinery is not running, and the expenses are much increased when heavier discharges are required. Any number of lamps may be installed, but no more may be in use at any one time than the maximum for which the installation was intended.

The steam engines in the table are all given of higher power than is actually required, in order to permit of a large margin for variations in boiler pressure, so as never to be short of steam; and since the power delivered varies with steam pressure, this gives a reserve, if

the daily boiler pressure be below the maximum permissible.

Under the ordinary conditions here assumed, £2 per lamp has been allowed for wiring, switch, lamp, holder, and fuse, including simple fittings.

If the installation is carried out in the most perfect style, including first-class distributing and fuse-boards, the expense may rise to £3 per lamp, or even more; but as a rule such perfection is not required.

Elaborate fittings are not necessary, so that, if they are desired, their cost must be added, which will vary according to their number, and to the taste of the owner.

The prices of the leading manufacturers for dynamos, engines, wire, and all electrical requisites are much the same, and there is no reason for choosing one maker rather than another, provided that the most suitable and the best articles are obtained. It must be always borne in mind that some manufacturers make a speciality of certain classes of goods, and, in order to secure the most modern and the most durable articles for an installation, several firms should be employed, permitting each to supply their special goods.

Some object to so many automatic appliances, but this is unreasonable, because failure scarcely ever occurs; and when this does happen, matters are no worse than if these appliances had not been there; a cut-out going indicates the event, and no harm is done. Mankind fails at least a hundred times to one compared with the failure of a mechanical contrivance.

The public is still so ignorant on electrical matters that some scheme should be set on foot to enlighten them. Even professionals suffer from the want of knowledge of the many forms of apparatus existing at a particular moment. In fact, nothing short of a complete museum of appliances, connected with electric lighting, is required, with competent persons to explain their various uses. Since there are difficulties in the way of such a museum, the author suggests another means of carrying it out.

An association, with a large capital, might be formed, and called "The Electrical Association," to be conducted by able business men, assisted by one or two scientific experts. The board of management should not be permitted to hold shares, or have an interest, in any other electrical concern. It would be the duty of the association to collect in some suitable building examples of work from all the electrical manufacturers, and to engage competent persons to explain, for a small charge, the articles to those requiring information respecting them. The fees and the commission allowed by makers on goods sold through the influence of this association should go towards paying the expenses of the company, and interest not to exceed 5 per cent. on the capital. The chief difficulty in the way of carrying out this suggestion is that which Diogenes encountered, viz., to find an honest (in the sense of disinterested) man to place on the management; for it is well known that most persons have some direct or indirect interest in electric lighting matters. But, if such

an association could be established the advantages to be gained are evident.

An intending user of the electric light having no special knowledge would go to this place, and see all that practically exists for electric lighting purposes, and the exhibits are explained to him, without prejudice, which is the one difficulty at the present time. He can then make his choice by the exercise of his own judgment instead of pursuing the usual course, viz., that of buying a thing to-day because it is much praised by the seller, regretting his purchase to-morrow, having meanwhile seen something better. The common remarks of "waiting to see what is the best," and "whom can we trust? for all naturally try to sell their own manufactures, whether they are best or not," would then no longer be heard.

The manufacturers themselves would be great gainers, as such an association would not only advance electric lighting to a great degree, but would render them perfectly free from trade jealousies.

It cannot be too strongly recommended to those intending to put up the electric light, and who may not possess the necessary technical knowledge, that their best course is to employ a competent electrical engineer to draw up the specifications, examine the contractors' estimate, pass the work when completed, and to satisfy the insurance office inspector and any other authority, instead of following the usual course of committing the whole matter to the contractors only. The method of proceeding here recommended will, in all cases, be found the cheapest and most satisfactory.

The tables which follow were made before electric lighting had been extended to the degree it has now attained. The author has, therefore, had an opportunity of comparing a large number of estimates, given by various contractors and carried out since that time, with his estimates; and it is gratifying to him to observe that, in all cases, the estimates have worked out extremely close to his figures. Inexperienced persons may use these tables, with confidence, to check contractors' estimates, leaving the engineer to see that the specification is satisfactory.

TABLE OF

No. of hours used per annum.	No. of 16 c.p. lamps in installation.	Cost of dynamo.	Fitting up dynamo, foundations, carriage, belting, switches, etc.	Nom. H.P. Otto gas engine.	I. H.P. Otto gas engine.	Cost of Otto gas engine.	Cost of carriage, erection, pipes, foundations, etc. Otto gas engine.	Cost of wiring, installation, lamps, switches, fuses, etc.	Nom. H.P. steam engine (Marshall).	Cost of Marshall eng ne and boiler.	Cost of steam engine - foundations, carriage, erection, etc.	Cost of simple governor.	Cost of complete governors.	Cost of automatic switches.	Cost of switch-board for accumulator and instruments.	Accumulator only.	Erection, shelves, carriage, etc.	Cost of installation, no accumulator.	Cost of installation, with accumulator.
		£	£			£	£	£		£	£	£	£	£	£	£	£	£	£
2000	25	35	15	2	4	133	32	50	...	...	...	15	70	30	40	90	10	270	415
2000	40	45	15	3½	6	174	36	80	...	...	...	15	70	30	40	162	48	350	605
2000	45	50	15	...	...	...	...	90	3	167	53	15	70	30	40	162	48	375	630
2000	50	50	15	4	8	184	36	100	...	...	...	15	70	30	40	180	50	390	665
2000	60	60	15	...	...	...	...	120	4	206	44	15	100	30	60	180	50	445	720
2000	90	90	15	7	14	225	35	180	...	...	...	15	100	30	60	243	57	545	920
2000	90	90	15	...	..	...	...	180	6	238	72	15	100	30	60	243	57	595	970
2000	120	105	20	...	.	...	...	240	8	265	85	15	100	30	60	243	57	715	1090

ESTIMATES.

Cost of auto. installation with accumulator.	Average cost per lamp, no accumulator, capital account.	Average cost per lamp, with accumulator, capital account.	Average cost per lamp, auto. installation, capital account.	Annual expense, actual outgoings, no accumulator.	Annual expense, actual outgoings, with accumulator.	Annual expense, actual outgoings, auto. installation, with accumulator.	Average annual cost per lamp, working expenses, no accumulator, no interest or sinking fund.	Average annual cost per lamp, working expenses, with accumulator, no interest or sinking fund.	Average annual cost per lamp, working expenses, auto. installation, with accumulator, no interest or sinking fund.	Annual cost, including interest and sinking fund, no accumulator.	Annual cost, including interest and sinking fund, with accumulator.	Annual cost, including interest and sinking fund, auto. installation, with accumulator.	Average cost a year per lamp, with interest and sinking fund, no accumulator.	Average cost a year per lamp, with interest and sinking fund, with accumulator.	Average cost a year per lamp, with interest and sinking fund, auto. installation, with accumulator.
£	£ s.	£	£	£	£	£	£ s.	£ s.	£ s.	£	£	£	£ s.	£ s.	£ s.
515	11 0	17	21	95	103	106	3 16	4 2	4 4	105	136	146	4 4	5 10	6 0
705	9 0	14	18	124	137	142	3 6	3 9	3 10	150	184	194	3 15	4 10	5 0
730	8 0	13	16	137	150	155	3 1	3 6	3 9	164	200	210	3 15	4 9	4 10
765	8 0	13	15	148	161	166	3 7	3 12	3 18	178	214	224	3 12	4 4	4 10
850	7 5	12	14	167	180	185	2 15	3 0	3 2	200	239	252	3 7	4 0	4 3
1050	6 0	10	12	230	250	256	2 9	2 15	2 15	270	322	335	3 0	3 10	3 14
1100	6 5	11	12	232	252	258	2 9	2 15	2 15	277	329	342	3 0	3 12	3 15
1220	6 0	9	10	292	312	318	2 8	2 11	2 13	345	401	414	2 16	3 7	3 9

CHAPTER IX.

A BRIEF ACCOUNT OF THE BROOMHILL INSTALLATION AND OF THE WIRING AT GROSVENOR STREET, WITH RESULTS.

ELECTRIC lighting was commenced in an elementary manner in 1874, with primary batteries, to obtain a better light in the workshop at night. About a year later a Gramme dynamo was used. From that time, till 1881, continued advance was made in electrical science and in apparatus. Therefore, until 1881, it was deemed advisable to make no changes, but in that year electric lighting assumed a more settled condition.

The Broomhill installation then underwent an alteration. A 16 candles Jablochkoff dynamo, with self-contained exciter, was erected.

In the following year, much attention was given to accumulators for their supply to the public; and one of the first made was sent to Broomhill, for lighting purposes, by the Electrical Power Storage Company. In fact, till 1883, there was no really good cell made; and those at present in use are very similar; but they now last well, compared with earlier makes. This is almost entirely due to a better knowledge of management. That is the whole secret of the matter.

Broomhill saw three distinct installations between September, 1882, and September, 1883. The Jablochkoff dynamo disappeared, a Siemens 60 20-c.p. 50-volt machine was erected, and lamps were placed in the private sitting-rooms of the house. In February, 1883, this was changed for a 100-volt dynamo; and great advantages accrued in consequence. A better light was obtained, and the number of lamps could be slightly increased. This was one of the first 100-volt installations. Four gas engines were put up during this period. In March, 1883, another installation was erected with a 6 h.p. steam engine, and two 50-light Siemens machines coupled. This installation ran admirably till November, 1883. Breakdowns occurred, at first, for want of water to feed the boiler; but this was eventually remedied, and all went on smoothly.

The first accumulator was introduced in the autumn of 1883, and it proved a great blessing.

This battery consisted of what was then termed 1 e.h.p. cells, fifty-five in number. Endless devices were made in the workshop to be placed in the installation, so as to render everything automatic; and this was at last accomplished.

After the knowledge gained by past experience, it was decided to put up a model installation. This was done, and no hitch of any kind has ever occurred since the start in the summer of 1884.

It may be remembered that, about September, 1883, the Electrical Power Storage Company declined to supply any more cells for a time; because it was their

intention to introduce some improvements, but which, in the end, turned out to be "castles in the air." Broomhill, however, profited by this circumstance, for the Company undertook, as a favour, to supply a battery during that period on the understanding that, if it failed, they would replace it free of expense. This battery eventually broke down, but naturally some experience had been gained through its use. In August, 1884, the accumulator sent in place of the old one arrived, the cells being of the same size as before, but with thick plates, such as are now termed "Regulator type."

This accumulator, however, proved unsatisfactory; and arrangements were made to exchange for it a new set of cells of the hanging type, with plates of the size "L." A new accumulator room, with all necessary arrangements, was built to receive the new cells.

In August, 1885, this battery was erected.

The engines, boilers, and other machinery are in duplicate, and large enough to meet the heaviest load likely to be put on. There are four dynamos; and of these there are three, any one of which can do all the work required. The fourth is able to produce a current having a pressure of 60 or 100 volts at will. It may, therefore, be employed for lighting the house, and the arc lamp on the tower, which has an illuminating power of 20,000 candles. For this latter purpose it is always used. There are also about thirty motors.

Each engine is Marshall's 10 nom. h.p., giving 56 ind. h.p. when required. The boilers, by the same maker,

are of the Cornish multitubular pattern, and 12 nom. h.p. size.

In order to put up a larger accumulator, consisting of 108 cells, a new place was built in 1886, provided with many improvements; and up to this date no want seems to have been omitted.

The convenient plan of placing resistances in the dynamo shunt circuit, in order to vary the E.M.F., or obtain a constant current, was probably for the first time used at Broomhill, as well as the counter E.M.F. regulating methods.

There are about 500 lamps, *i.e.*, equal to 500 16 c.p. lamps (these lamps now supplant the old 20 c.p.), for many are 100, 50, 32, 25, and 8 c.p. The E.M.F. employed is 100 volts. The greatest number of lamps used at any one time has rarely exceeded 200; and, together with these, the arc lamp, taking forty to fifty ampères, and one or two motors. In the stables, cellars, and all conceivable places, as well as the house, electric lamps are to be found, so that no gas is used except for heating, cooking, and laboratory work. The switches in every case are placed upon the shutting door-posts. Every possible kind of work in metal or wood, from watchwork to large constructions, can be done in the workshop by means of machinery run by motors, almost every machine having one to itself. Photography is also practised by electric light, and for the dark-room the electric lamp offers exceptional convenience. Numberless devices are in use about the house and elsewhere, advantage being taken of the benefits of the

current for every conceivable purpose, even for the churning of butter and the working of mechanical toys. All the electrical arrangements in and out of the engine-house are automatic. The whole of the buildings were erected, and the electrical and engineering work carried out by the owner, without professional assistance, and by men trained on the spot.

The installation is put up throughout in a most perfect manner, and the buildings are very substantial and also well fitted. The maximum power is 1,000 16-c.p. lamps, when both engines are running; and there are 108 23-plate cells at work. The cost of the buildings and installation has been about £6,000. A private gas-works, with piping and gas fittings, brackets and chandeliers, for the same number of lights, would have cost about the same, or even more. The sinking fund in either case would be much the same. But in regard to the working expenses, the electric light has proved more favourable than gas. This statement is made authoritatively, for there was a private gasworks at Broomhill, before the electric light was instituted. It was at one time a question between building larger gasworks or adopting the new light, but calculations were in favour of the latter, and practice has justified that choice. Accounts are kept of every penny spent on the light, as well as the number of ampère hours used. The cost-book has been accurately kept since 1884, and runs thus: For 1884, the total outgoings amounted to £165, being at the rate of 2d. an hour for every 16 c.p. lamp; in 1885 the expenses were £181,

or 1¼d. an hour per 16-c.p. lamp; the total expenses in 1886 were £210, being at the rate of $\frac{1}{7}$d. per 16-c.p. lamp, when the current used for the motors was included. The expenses comprise wages, coal, oil, waste, washers, repairs, lamp renewals, insurance, and other charges. A six cubic feet gas burner costs ¼d. an hour, when gas is sold at 3s. 6d. per 1,000 cubic feet; so that, in 1886, the electric light proved far cheaper than its rival, when sinking fund and interest are omitted. In the event of a private gasworks being used, these latter charges need not be taken into account; because they would be about equal for both methods of lighting. The reason why the expenses increased each year, and at the same time greater economy secured, is twofold—first, as confidence in the electric light increased, the latter was used more and more, and, finally, without stint, so that the installation was gradually worked nearer the point of greatest economy; and, secondly, numbers of improvements were introduced, in regard to management as well as apparatus.

For the year 1887 the working expenses were £183, and every 16-c.p. lamp cost a little under one penny per hour, or six times more than in 1886. There were two reasons for this increase: First, the house was shut up nearly six months out of the year, during which time the installation was lying idle, although wages and other expenses continued during that time; secondly, on account of special circumstances, no parties were given, and there was no staying company, so that there was a great decrease in the consumption of current.

The expenses since the year 1887, though very low, in no way form a basis for calculating the cost of the light, because the family had been a great deal away. The demand on the current was only made at intervals, and only during short periods. It may be mentioned that the standing expenses, if no light were to be used, are approximately £120 a year, made up as follows:—£85 for wages, £10 for boiler insurance, £3 for fire insurance, and the remainder for sundries, such as materials for keeping the machinery and buildings clean painting, and other small matters.

The expenses for the years 1886 and 1887 teach a good lesson. The extra expenditure of only £27 caused a sixfold decrease in the cost of the light, and proves how necessary it is to base estimates, not on what an installation can supply, but on what amount of current is likely to be used on the average in the course of the year.

Putting into figures the 1887 current consumption for light, apart from current employed for motors, the ampère hours used were approximately 85,000, at 100 volts. This gives 8,500 B.T.U., which represents a cost of about fivepence per unit, as compared with nearly one penny per unit in 1886, when the working of the system came nearer the point of best economy; and it must be borne in mind that this sum takes into account all renewals of lamps, minor repairs in the house, repairs to wiring, and all other expenses which are not included in the price per unit of public companies.

With the perfect methods of governing in operation

at Broomhill, whereby the variation of pressure is limited to 1%, the lamp-life approaches, if it does not even exceed, 3,000 hours; so that the replacing of an old lamp by a new one becomes a "red-letter day."

Considerably over £2,000 was expended in experiments, before arriving at the present satisfactory position.

The cost of this installation may be divided into five parts. Each complete working half cost £1,500; the cells £500, including all their fittings; extra dynamos, machinery, and so forth, £1,000; the engine-house buildings (which are extensive), £1,000; testing apparatus, lamps, wires, motors, and other fittings, £500; making a total of £6,000, or thereabouts.

At the present moment gas engines of 14 nom. h.p., giving 33 ind. h.p., are in course of erection, to replace the steam engines. Beyond an outlay of about £1,000, the working expenses will remain the same. Against this outlay the money to be realised by the sale of the steam engines and boilers may be set off. The reasons for the change are that gas engines have been greatly improved, and require much less attention than steam engines, they can also be started at a moment's notice. The engines are to be started by means of a 1 or 2 h.p. motor. The armature shaft will have a flexible shaft attached to it, and the end of this will rotate a pulley carried on a lever which is hinged to the floor. When used, a man will raise the lever, thus pressing the pulley (made of wood) against the flywheel, and so rotate it by friction, when the motor is started. The engine once in motion, the

lever is allowed to rest on the ground, where it will remain when out of use.

The author's house in Grosvenor Street is supplied by alternating current from the London Electric Light Supply Corporation, and is fitted up in the following manner. The pressure on the supply mains is 2,400 volts. This is reduced to 100 volts in the house by means of a Ferranti transformer, placed in a well ventilated fire-proof construction in the area. The primary wires are carried from the roof to the transformer in a stout leaden pipe, to prevent accidents to person as well as injury to the cables. In this transformer house there are the D.P. primary circuit fuses and the D.P. primary switch, also the D.P. secondary main fuses of Cockburn pattern, the latter fuse-board being of the author's special make, to enable a fuse to be replaced without loss of time; and there is likewise a lamp. The transformer is for 120 ampères on the secondary circuit. The primary circuit, consequently, is intended to pass five ampères. The secondary mains, 19/14 in size, pass on to the study, where the distributing board is situated. The latter is made of slate, and is cut up and mounted upon ebonite in such a manner that there is no connection between any portions having opposite polarities, excepting across the ebonite. Wherever portions, having opposite polarities, are situated near to one another, a piece of wood is placed projecting from the board above the level of any metal work, which prevents the possibility of an accident by making a short circuit when the fuses or connections are touched for any purpose.

This board has upon it the ammeter switch, a connector and switch for the volt meter, a D.P. main switch, and seven D.P. fuses. From these latter, secondary mains, 7/16 in size, proceed to every floor, also to the stables and laboratory. On each floor the secondary main undergoes distribution from a fuse-board, below which there is a D.P. switch to cut the current from the fuse-board when required. From each fuse-board the wires proceed to the various lamps on that floor, with a 7/18 cable no smaller hidden conductor being used throughout the house. The instruments in use are the best form of Siemens' dynamometer, Sir William Thomson's ampère gauge and marine voltmeter. The cables employed throughout are the Indiarubber and Gutta Percha Company's highest insulation type. These are laid in white pine casing, shellac-varnished inside, and, when laid under floors, project beyond the skirtings. Thin sheet lead is placed over the casing after the cover has been fixed on it. Ceiling plates and switches are of slate, boiled in paraffin wax. These, together with the wall connectors of the author's pattern, as well as the brackets and fittings, were all specially made for the installation, and contain many improvements. It is evident that, with the exception of the fuses upon the secondary mains and those upon the fuse-boards, others are not required, save at those points where lamps are attached. These are placed on the wall or ceiling, where the 7/18 cable stops. The twin wire employed is made by Messrs. Johnson & Phillips; it is well insulated, and in size is 40/40. All joints, which would have to be

made outside the house, are arranged in such a way that they are made in one place, and put into a joint box filled with pitch. The whole of the lamps, with very few exceptions, are single-light pendants, as at Broomhill, this method of lighting having been found most agreeable as well as economical, and in most cases every lamp has a switch to itself. There are portable lamp fittings in every room, and the total number of lamps installed is about 200. The expense has been considerable, in consequence of the large size of the cables used throughout. The cost has been between £700 and £800, which includes everything. In the event of removal to another house at the termination of the lease, the boards, instruments, fittings, and so forth, could be taken away. The loss would be in respect of the portions left, viz., the wiring only, which, by itself, has cost about £350. The lease runs out in the course of twenty years, and all the fittings being of superior manufacture, it is evident that this large expenditure was justified, as they will be as good at the end of that period as they are to-day. The usual practice of buying the cheapest for the purpose required is an unwise policy, because they are continually getting out of repair and will not bear removal to another place. Many instances have come under the author's notice of installations which have had to be done twice over simply because they were not properly done in the first instance, and which put the owners to an expense far exceeding that which would have been the case had first-class work been done at first, apart from the immense inconvenience and danger

to which life and property had been exposed. This consideration led to the installation at Grosvenor Street being carried out in a manner so thorough. All the lamps are obscured, thus equalising the light in a room to a greater extent than when clear glass ones are used. besides being agreeable to the eye. In fact, obscured lamps are really more economical to light with than clear ones, which is difficult to believe until the experiment has been tried. The pendant lamps have a convenience which is very great. Should it be found that a room is insufficiently lighted at its lower part, the pendant cords may be lengthened two or three inches and the desired result will then, probably, be obtained without the necessity of placing higher candle-power lamps or of increasing their number. Every circuit from the fuse-boards carries from three to seven lamps of 16 c.p. The general arrangements in regard to positions of switches are the same as at Broomhill.

The pressure given by the supplying company, whose machinery at the present moment is overtaxed, is from five to ten per cent. below the normal; but, when their new installation at Deptford is completed, they expect to remedy the difficulty by the large reserve of power which they will then have at command. Nevertheless, this low pressure has proved extremely inconvenient, since the lamps at times show barely half the light they were intended to give. In order to overcome this difficulty, the author obtained the assistance of Mr. Gisbert Kapp, who devised the apparatus illustrated and described in the chapter on alternating currents, and

which has proved an inestimable boon. In the designing of all switches, ceiling plates, connectors, and apparatus, special care has been taken that all portions in connection with the conductors are perfectly insulated from the hand, and in such a way that no parts carrying current can be touched without removing a cover or some equivalent protection. In this manner danger to life, which might arise from the primary and secondary circuits in the transformer coming in contact, is completely averted.

It will be noticed that three things must be observed in wiring houses, and especially rule 3, when the supply is from a public source, for, in this case, the potential employed on the primary mains is usually very high, and, therefore, dangerous to life; but, even in low pressure installations, there are many advantages in observing this rule.

1. The conductors should be large enough to permit of any lamp habitually employed being changed for others giving a higher candle power.

2. All conductors should be laid and protected by fuses, and apparatus so designed as to eliminate the dangers of short circuit, or of other accidents which might lead to fire.

3. All portions carrying current should be carefully covered for protection to life.

INDEX.

D

WILLIAM RIDER AND SON, PRINTERS, LONDON.

2, WHITE HART STREET,
PATERNOSTER SQUARE, E.C.

WHITTAKER & CO.'S
LIST OF
Classical, Educational, and Technical Works.

CONTENTS.

Dec., 1889.

Mr. Leland's Educational Publications.

Third Edition, Crown 8vo, Cloth, 6s.

PRACTICAL EDUCATION.

A WORK ON

PREPARING THE MEMORY, DEVELOPING QUICKNESS OF PERCEPTION, AND TRAINING THE CONSTRUCTIVE FACULTIES.

BY CHARLES G. LELAND.

Author of "The Minor Arts," "Twelve Manuals of Art Work," "The Album of Repoussé Work," Industrial Art in Education, or Circular No. 4, 1882," "Hints on Self-Education," etc.

MR. LELAND was the first person to introduce *Industrial Art* as a branch of education in the public schools of America. The Bureau of Education at Washington, observing the success of his work, employed him in 1862 to write a pamphlet showing how hand-work could be taken or taught in schools and families. It is usual to issue only 15,000 of these pamphlets, but so great was the demand for this that in two years after its issue more than 60,000 were given to applicants. This work will be found greatly enlarged in "Practical Education." Owing to it thousands of schools, classes, or clubs of industrial art were established in England, America and Austria. As at present a great demand exists for information as to organizing Technical Education, this forms the first part of the work. In it the author indicates that all the confusion and difference of opinion which at present prevails as to this subject, may very easily be obviated by simply beginning by teaching the youngest the easiest arts of which they are capable, and by thence gradually leading them on to more advanced work.

"The basis of Mr. Leland's theory," says a reviewer, "is that before learning, children should acquire the art of learning. It is not enough to fill the memory, memory must first be created. By training children to merely memorize, extraordinary power in this respect is to be attained in a few months. With this is associated exercises in quickness of perception, which are at first purely mechanical, and range from merely training the eye to mental arithmetic, and problems in all branches of education. Memory and quickness of perception blend in the development of the constructive faculties or hand-work. Attention or interest is the final factor in this system."

"*Mr. Leland's book will have a wide circulation. It deals with the whole subject in such a downright practical fashion, and is so much the result of long personal experience and observation, as to render it a veritable mine of valuable suggestions.*"—BRITISH ARCHITECT.

"*It has little of the dryness usually associated with such books; and no teacher can read its thoughtful pages without imbibing many valuable ideas.*"—SCOTTISH EDUCATIONAL NEWS.

"*Strongly to be recommended.*"—CHEMICAL NEWS.

"*This valuable little work.*"—LIVERPOOL DAILY POST.

"*Many of Mr. Leland's suggestions might be carried out advantageously among the young folks in our large towns and villages.*"—NORTHERN WHIG.

Minor Arts and Industries.

A SERIES OF ILLUSTRATED AND PRACTICAL MANUALS FOR SCHOOL USE AND SELF-INSTRUCTION.

EDITED BY CHARLES G. LELAND.

This series of manuals on "The Minor Arts and Industries" is designed on the lines laid down in Mr. Leland's treatise on education. Each handbook will present the subject with which it deals in a thoroughly popular and practical manner; the lessons carry the student on his road step by step from the veriest elements to the point where the most advanced works fitly find their place in his course of study; in short, the greatest pains are taken to ensure a thorough mastery of the rudiments of each subject, and to so clearly state each lesson, illustrating it where necessary by plans and drawings, that even very young children may be interested in and trained to practical work. On similar grounds the self-taught student will find these manuals an invaluable aid to his studies.

Part 1 *now ready, Paper cover,* 1*s. or in cloth,* 1*s.* 6*d.*

DRAWING AND DESIGNING:

IN A SERIES OF LESSONS, WITH NUMEROUS ILLUSTRATIONS,

BY CHARLES G. LELAND, M.A., F.R.L.S.

WOOD CARVING: with numerous illustrations, chiefly from original designs. By CHARLES G. LELAND. [*In the Press.*

Other volumes will follow at intervals, amongst the subjects of which may be named—

MODELLING.
LEATHER WORK.
METAL WORK.
CARPENTERING.

GREEK AND LATIN.

Bibliotheca Classica.

A Series of Greek and Latin Authors, with English Notes, edited by eminent Scholars. 8*vo.*

ÆSCHYLUS. By F. A. Paley, M.A. 8*s.*

CICERO'S ORATIONS. By G. Long, M.A. 4 vols. 8*s.* each.

DEMOSTHENES. By R. Whiston, M.A. 2 vols. 8*s.* each.

EURIPIDES. By F. A. Paley, M.A. 3 vols. 8*s.* each.

HERODOTUS. By Rev. J. W. Blakesley, B.D. 2 vols. 12*s.*

HESIOD. By F. A. Paley, M.A. 5*s.*

HOMER. By F. A. Paley, M.A. Vol. I. 8*s.* Vol. II. 6*s.*

HORACE. By Rev. A. J. Macleane, M.A. 8*s.*

JUVENAL AND PERSIUS. By Rev. A. J. Macleane, M.A. 6*s.*

LUCAN. The Pharsalia. By C. E. Haskins, M.A., and W. E. Heitland, M.A. 14*s.*

PLATO. By W. H. Thompson, D.D. 2 vols. 5*s.* each.

SOPHOCLES. Vol. I. By Rev. F. H. Blaydes, M.A. 8*s.*

——— Vol. II. Philoctetes—Electra—Ajax and Trachiniæ. By F. A. Paley, M.A. 6*s.*

TACITUS: The Annals. By the Rev. P. Frost. 8*s.*

TERENCE. By E. St. J. Parry, M.A. 9*s.*

VIRGIL. By J. Conington, M.A. 3 vols. 10*s.* 6*d.* each.

*** In some cases the volumes cannot be sold separately. The few copies that remain are reserved for complete sets, which may be obtained, at present, for 9*l.*

Grammar School Classics.

A Series of Greek and Latin Authors, with English Notes. Fcap. 8vo.

CÆSAR: DE BELLO GALLICO. By George Long, M.A. 4*s.*

——— Books I.-III. For Junior Classes. By George Long, M.A. 1*s.* 6*d.*

——— Books IV. and V. in 1 vol. 1*s.* 6*d.*

——— Books VI. and VII. in 1 vol. 1*s.* 6*d.*

CATULLUS, TIBULLUS, AND PROPERTIUS. Selected Poems. With Life. By Rev. A. H. Wratislaw. 2*s.* 6*d.*

CICERO: DE SENECTUTE, DE AMICITIA, and SELECT EPISTLES. By George Long, M.A. 3*s.*

CORNELIUS NEPOS. By Rev. J. F. Macmichael. 2*s.*

HOMER: ILIAD. Books I.-XII. By F. A. Paley, M.A. 4*s.* 6*d.*
Books I.-VI., 2*s.* 6*d.*; Books VII.-XII., 2*s.* 6*d.*

HORACE. With Life. By A. J. Macleane, M.A. 3*s.* 6*d.* In 2 Parts: Odes, 2*s.*; Satires and Epistles, 2*s.*

JUVENAL: SIXTEEN SATIRES. By H. Prior, M.A. 3*s.* 6*d.*

MARTIAL: SELECT EPIGRAMS. With Life. By F. A. Paley, M.A. 4*s.* 6*d.*

OVID: The FASTI. By F. A. Paley, M.A. 3*s.* 6*d.*

——— Books I. and II. in 1 vol. 1*s.* 6*d.*

——— Books III. and IV. in 1 vol. 1*s.* 6*d.*

——— Books V. and VI. in 1 vol. 1*s.* 6*d.*

SALLUST: CATILINA and JUGURTHA. With Life. By G. Long, M.A., and J. G. Frazer. 3*s.* 6*d.* Catilina, 2*s.* Jugurtha, 2*s.*

TACITUS: GERMANIA and AGRICOLA. By Rev. P. Frost. 2*s.* 6*d.*

VIRGIL: BUCOLICS, GEORGICS, and ÆNEID, Books I.-IV. Abridged from Professor Conington's edition. 4*s*. 6*d*.

—— ÆNEID, Books V.-XII. 4*s*. 6*d*.
Also in 9 *separate volumes*, 1*s*. 6*d*. *each*.

XENOPHON: The ANABASIS. With Life. By Rev. J. F. Macmichael. 3*s*. 6*d*.
Also in 4 *separate volumes*, 1*s*. 6*d*. *each*.

—— The CYROPÆDIA. By G. M. Gorham, M.A. 3*s*. 6*d*.

—— Books I. and II. in 1 vol. 1*s*. 6*d*.

—— Books V. and VI. in 1 vol. 1*s*. 6*d*.

—— MEMORABILIA. By Percival Frost, M.A. 3*s*.

A GRAMMAR-SCHOOL ATLAS OF CLASSICAL GEOGRAPHY, containing Ten selected Maps. Imperial 8vo. 3*s*.
Uniform with the Series.

THE NEW TESTAMENT, in Greek. With English Notes, &c. By Rev. J. F. Macmichael. 4*s*. 6*d*. Separate parts, St. Matthew, St. Mark, St. Luke, St. John, Acts, 6*d*. each, sewed.

Lower Form Series.

With Notes and Vocabularies.

ECLOGÆ LATINÆ; OR, FIRST LATIN READING-BOOK, WITH ENGLISH NOTES AND A DICTIONARY. By the late Rev. P. Frost, M.A. New Edition. Fcap. 8vo. 1*s*. 6*d*.

LATIN VOCABULARIES FOR REPETITION. By A. M. M. Stedman, M.A. 2nd Edition, revised. Fcap. 8vo. 1*s*. 6*d*.

EASY LATIN PASSAGES FOR UNSEEN TRANSLATION. By A. M. M. Stedman, M.A. Fcap. 8vo. 1*s*. 6*d*.

VIRGIL'S ÆNEID. Book I. Abridged from Conington's Edition by Rev. J. G. Sheppard, D.C.L. With Vocabulary by W. F. R. Shilleto. 1*s.* 6*d.* [*Now ready.*

CÆSAR: DE BELLO GALLICO. Book I. With Notes by George Long, M.A., and Vocabulary by W. F. R. Shilleto. 1*s.* 6*d.* [Book II. *in the press.*

TALES FOR LATIN PROSE COMPOSITION. With Notes and Vocabulary. By G. H. Wells, M.A. 2*s.*

MATERIALS FOR LATIN PROSE COMPOSITION. By the late Rev. P. Frost, M.A. New Edition. Fcap. 8vo. 2*s.* Key (for Tutors only), 4*s.*

A LATIN VERSE-BOOK. AN INTRODUCTORY WORK ON HEXAMETERS AND PENTAMETERS. By the late Rev. P. Frost, M.A. New Edition. Fcap. 8vo. 2*s.* Key (for Tutors only), 5*s.*

ANALECTA GRÆCA MINORA, with INTRODUCTORY SENTENCES, ENGLISH NOTES, AND A DICTIONARY. By the late Rev. P. Frost, M.A. New Edition. Fcap. 8vo. 2*s.*

GREEK TESTAMENT SELECTIONS. By A. M. M. Stedman, M.A. 2nd Edition, enlarged, with Notes and Vocabulary. Fcap. 8vo. 2*s.* 6*d.*

Cambridge Texts with Notes.

A Selection of the most usually read of the Greek and Latin Authors, Annotated for Schools. Fcap. 8vo, 1*s.* 6*d. each, with exceptions.*

EURIPIDES. ALCESTIS—MEDEA—HIPPOLYTUS—HECUBA—BACCHÆ—ION (2*s.*)—ORESTES—PHOENISSÆ—TROADES—HERCULES FURENS—ANDROMACHE—IPHIGENIA IN TAURIS—SUPPLICES. By F. A. Paley, M.A., LL.D.

ÆSCHYLUS. PROMETHEUS VINCTUS—SEPTEM CONTRA THEBAS—AGAMEMNON—PERSÆ—EUMENIDES—CHŒPHORŒ. By F. A. Paley, M.A., LL.D.

SOPHOCLES. ŒDIPUS TYRANNUS—ŒDIPUS COLONEUS—ANTIGONE—ELECTRA—AJAX. By F. A. Paley, M.A., LL.D.

THUCYDIDES. BOOK IV. By. F. A. Paley, M.A., LL.D.

XENOPHON. HELLENICA. BOOK II. By Rev. L. D. Dowdall, M.A.

——— ANABASIS. Edited by Rev. J. F. Macmichael. *New edition*, revised by J. E. Melhuish, M.A. In 6 vols. Book I. (with Life, Introduction, Itinerary, &c.); Books II. and III. 2*s.*; Book IV., Book V., Book VI., Book VII.

HOMER. ILIAD. BOOK I. By F. A. Paley, M.A., LL.D. 1*s.*

VIRGIL (abridged from Conington's edition). BUCOLICS: GEORGICS, 2 parts: ÆNEID, 9 parts.

TERENCE. ANDRIA—HAUTON TIMORUMENOS—PHORMIO—ADELPHOE. By Professor Wagner, Ph.D.

CICERO. DE SENECTUTE—DE AMICITIA—EPISTOLÆ SELECTÆ. By G. Long, M.A.

OVID. SELECTIONS. By A. J. Macleane, M.A.

Others in preparation.

Cambridge Greek and Latin Texts.

These Texts, which are clearly printed at the Cambridge University Press, on good paper, and bound in a handy form, have been reduced in price, and will now meet the requirements of masters who wish to use Text and Notes separately.

ÆSCHYLUS. By F. A. Paley, M.A. 2*s.*

CÆSAR: DE BELLO GALLICO. By G. Long, M.A. 1*s.* 6*d.*

CICERO: DE SENECTUTE et DE AMICITIA, et EPISTOLÆ SELECTÆ. By G. Long, M.A. 1*s.* 6*d.*

CICERONIS ORATIONES. Vol. I. (in Verrem.) By G. Long, M.A. *2s. 6d.*

EURIPIDES. By F. A. Paley, M.A. 3 vols., each *2s.*

——— Vol. I. Rhesus—Medea—Hippolytus—Alcestis—Heraclidæ—Supplices—Troades—Index.

——— Vol. II. Ion—Helena—Andromache—Electra—Bacchæ—Hecuba—Index.

——— Vol. III. Hercules Furens—Phœnissæ—Orestes—Iphigenia in Tauris—Iphigenia in Aulide—Cyclops—Index.

HERODOTUS. By J. G. Blakesley, B.D. 2 vols., each *2s. 6d.*

HOMERI ILIAS. I.-XII. By F. A. Paley, M.A. *1s. 6d.*

HORATIUS. By A. J. Macleane, M.A. *1s. 6d.*

JUVENAL ET PERSIUS. By A. J. Macleane, M.A. *1s. 6d.*

LUCRETIUS. By H. A. J. Munro, M.A. *2s.*

SALLUSTI CRISPI CATILINA ET JUGURTHA. By G. Long, M.A. *1s. 6d.*

SOPHOCLES. By F. A. Paley, M.A. *2s. 6d.*

TERENTI COMŒDIÆ. By W. Wagner, Ph.D. *2s.*

THUCYDIDES. By J. G. Donaldson, D.D. 2 vols., each *2s.*

VERGILIUS. By J. Conington, M.A. *2s.*

XENOPHONTIS EXPEDITIO CYRI. By J. F. Macmichael, B.A. *1s. 6d.*

NOVUM TESTAMENTUM GRÆCE. By F. H. Scrivener, M.A. *4s. 6d.* An edition with wide margin for notes, half bound, *12s.*

Annotated Editions.

CICERO'S MINOR WORKS. De Officiis, &c. &c. With English Notes, by W. C. Tylor, LL.D. 12mo. cloth, 3*s*. 6*d*.

VIRGIL'S ÆNEID. With English Notes, by C. Anthon, LL.D. Adapted for use in English Schools by the Rev. F. Metcalfe, M.A. *New Edition*. 12mo. 7*s*. 6*d*.

Greek Class Books.

BEATSON'S PROGRESSIVE EXERCISES ON THE COMPOSITION OF GREEK IAMBIC VERSE. 12mo. cloth, 3*s*.

DAWSON'S GREEK-ENGLISH LEXICON TO THE NEW TESTAMENT. *New Edition*, by Dr. Tylor. 8vo. cloth, 9*s*.

NOVUM TESTAMENTUM GRÆCE. Textus Stephanici, 1550. Accedunt variæ Lectiones editionum Bezæ, Elzeviri, Lachmanni, Tischendorfii, Tregellesii, curante F. H. Scrivener, M.A. 4*s*. 6*d*. An Edition with wide margin for MS. Notes, 4to. half-bound morocco, 12*s*.

——— Textûs Stephanici, A.D. 1550, Cum variis Lectionibus Editionum Bezæ, Elzeviri, Lachmanni, Tischendorfii, Tregellesii, Westcott-Hortii, Versionis Anglicanæ Emendatorum, Curante F. H. A. Scrivener, A.M., D.C.L., LL.D., Accedunt Parallela S. Scripturæ Loca. Small post 8vo. cloth, pp. xvi.-598, 7*s*. 6*d*.

EDITIO MAJOR *containing, in addition to the matter in the other Edition, the Capitula (majora et minora) and the Eusebian Canons, the various Readings of Westcott and Hort, and those adopted by the Revisers; also a revised and much-enlarged series of References.*

——— VALPY'S. For the use of Schools. 12mo. cloth, 5*s*.

——— Edited by Rev. Macmichael. *See Grammar School Classics.*

Students' Editions of the Gospels and the Acts.

Crown 8vo. cloth.

THE GOSPEL OF S. MATTHEW. The Greek Text, with Critical, Grammatical, and Explanatory Notes, &c., by the late Rev. W. Trollope, M.A., re-edited by the Rev. W. H. Rowlandson, M.A. 5*s.*

GOSPEL OF S. MARK. The Greek Text, with Critical, Grammatical, and Explanatory Notes, Prolegomena, &c., by Rev. W. H. Rowlandson, M.A. 4*s.* 6*d.*

GOSPEL OF S. LUKE. The Greek Text, with Critical, Grammatical, and Explanatory Notes, &c., by the late Rev. W. Trollope, M.A., revised and re-edited by the Rev. W. H. Rowlandson, M.A. 5*s.*

ACTS OF THE APOSTLES. The Greek Text, with Critical, Grammatical, and Explanatory Notes, and Examination Questions, by Rev. W. Trollope, M.A., re-edited and revised by the Rev. G. F. Browne, M.A. 5*s.*

Latin Class Books.

BEDFORD'S PROPRIA QUÆ MARIBUS; or, Short Rules for the Genders of Latin Nouns, and a Latin Prosody. 12mo. 1*s.*

BOSSUT'S LATIN WORD BOOK; or, First Step to the Latin Language. 18mo. 1*s.*

—— LATIN PHRASE BOOK. 18mo. 1*s.*

FLORILEGIUM POETICUM. A Selection of Elegiac Extracts from Ovid and Tibullus. *New edition*, greatly enlarged with English Notes. By the late Rev. P. Frost, M.A. Fcap. 8vo. 2*s.*

GRADUS AD PARNASSUM; sive novus sinonymorum, epithetorum, versuum, ac phrasium poeticarum, thesaurus. *New edition.* By G. Pyper. 12mo. cloth, 7*s.*

—— BY VALPY. Whittaker's Improved edition. Latin and English. *New edition.* Royal 12mo. 7*s.* 6*d.*

STODDART'S NEW DELECTUS; or, Easy Steps to Latin Construing. For the use of Pupils commencing the Language. Adapted to the best Latin Grammars, with a Dictionary attached. *New edition.* 12mo. 4*s*.

PENROSE'S (REV. JOHN) Easy Exercises in Latin Elegiac Verse. *New edition.* 12mo. cloth, 2*s*.

——— Key to ditto, for Tutors only, 3*s*. 6*d*.

Atlases.

LONG'S ATLAS OF CLASSICAL GEOGRAPHY. Containing Twenty-four Maps. Constructed by William Hughes, F.R.G.S., and Edited by George Long, M.A. *New edition*, with Coloured Outlines, and an Index of Places. Royal 8vo. 6*s*.

LONG'S GRAMMAR SCHOOL ATLAS OF CLASSICAL GEOGRAPHY. Containing Ten Maps, selected from the larger Atlas. Constructed by W. Hughes, F.R.G.S., and edited by George Long, M.A. *New edition*, with Coloured Outlines. Royal 8vo. 3*s*.

English Language and Miscellaneous.

ALLEN AND CORNWELL'S SCHOOL GRAMMAR. Cloth, 1*s* 9*d*.

——— GRAMMAR FOR BEGINNERS. Cloth, 1*s*.

BELL'S MODERN READER AND SPEAKER. A Selection of Poetry and Prose, from the Writings of Eminent Authors. 12mo. 3*s*. 6*d*.

DUNCAN'S ENGLISH EXPOSITOR; or, Explanatory Spelling-book. Containing an Alphabetical Collection of all the most useful, proper, and elegant words in the English language, divided into Syllables, and properly accented. *New edition.* 12mo. 1*s*. 6*d*.

LATHAM'S (R. G.) DICTIONARY OF THE ENGLISH LANGUAGE. Abridged and condensed into one volume 8vo. cloth, 14*s*.

MACKAY (C.) A DICTIONARY OF LOWLAND SCOTCH. By Charles Mackay, LL.D. With an Introductory Chapter on the Poetry, Humour, and Literary History of the Scottish Language, and an Appendix of Scottish Proverbs. Large post 8vo. cloth, 7*s.* 6*d.* half bound, 8*s.* 6*d.*

——— SELECTED POEMS AND SONGS OF CHARLES MACKAY, LL.D. With a Commendatory and Critical Introduction by Eminent Writers. Wide foolscap 8vo. half cloth boards, 1*s.* 6*d.* Sewed, 1*s.*

WEBSTER'S DICTIONARY OF THE ENGLISH LANGUAGE. Including Scientific, Technical, and Biblical Words and Terms. *New edition*, with Supplement of over 4,600 New Words and Meanings. 4to. cloth, 1*l.* 1*s.*; half-calf, 1*l.* 10*s.* With Appendices, £1 11*s.* 6*d.*; half-calf, 2*l.*

SHAKESPEARE'S PLAYS, with Text and Introduction in English and German. Edited by C. Sachs, Prof. Ph D. 8vo. cloth, each Play or Number, 10*d.*

Now Ready:

1. Julius Cæsar.
2 Romeo and Juliet.
3. King Henry VIII.
4. King Lear.
5 Othello.
6. Hamlet.
7 A Midsummer Night's Dream.
8. Macbeth.
9. King John.
10. King Richard II.
11. King Henry IV. I.
12. ,, ,, II.
13. King Henry V.
14. King Richard III.
15. Cymbeline.
16. Coriolanus.
17. Antony and Cleopatra.
18. Merchant of Venice.
19. Much Ado about Nothing.

Others to follow.

"This edition will be quite a godsend to grown-up students of either language, for the ordinary class reading books are too childish to arrest their attention. The parallel paging saves the labour of using a dictionary, and the series is so low in price as to place it within the reach of all."
Saturday Review.

SHAKESPEARE REPRINTS. 1. King Lear. Parallel Texts of Quarto 1 and Folio 1. Edited by Dr. W. Vietor, of Marburg. Square 16mo. cloth, 3*s.* 6*d.*

The texts of the first quarto and folio, with collations from the later quartos and folios, are here printed in a compact and convenient volume, intended as a class-book in the University.

Miscellaneous Educational Books.

SEIDEL (ROBT.) INDUSTRIAL EDUCATION: A Pedagogic and Social Necessity. Crown 8vo. 4*s*.

WOODWARD (C.M.) THE MANUAL TRAINING SCHOOL, ITS AIMS, METHODS, AND RESULTS. With Figured Drawings of Shop Exercises in Woods and Metals. 8vo. 10*s*.

BIBLIOGRAPHY OF EDUCATION. Hints toward a Select and Descriptive Bibliography of Education. Arranged by Topics, and Indexed by Authors. By G. Stanley Hall, Professor, John Hopkins University, and John M. Mansfield. Post 8vo. cloth, pp. xvi.-309, 7*s*. 6*d*.

CHEPMELL'S (REV. DR.) SHORT COURSE OF GRECIAN, ROMAN, AND ENGLISH HISTORY. *New edition.* 12mo. 5*s*. Questions on, 12mo. 1*s*.

COLTON (B. P.) ELEMENTARY COURSE OF PRACTICAL ZOOLOGY. By B. P. Colton, A.M., Instructor in Biology, Ottawa High School. Crown 8vo. cloth, pp. xiv.-182, 4*s*. 6*d*.

CORNWELL'S SCHOOL GEOGRAPHY. 3*s*. 6*d*. With Thirty Maps on Steel, 5*s*. 6*d*.

—— GEOGRAPHY FOR BEGINNERS. 1*s*. With Questions, 1*s*. 4*d*.

DURHAM UNIVERSITY CALENDAR, with Almanack. Cloth, 1*s*. 6*d*. [*Published annually.*

JOYCE (P. W.) A HANDBOOK OF SCHOOL MANAGEMENT AND METHODS OF TEACHING. By P. W. Joyce, LL.D., &c. 11*th edition, revised.* Cloth, 3*s*. 6*d*.

A NATURE READER. Seaside and Wayside. By Julia McNair Wright. Cloth, 1*s*. 6*d*.

An elementary Reader for young children, designed to instil a love of Natural History. It treats of crabs, wasps, spiders, bees, and some univalve molluscs.

PINNOCK'S HISTORY OF ENGLAND. From the Invasion of Julius Cæsar. With a Biographical and Historical Dictionary. Questions for Examination, Genealogical Tables, Progress of Literature and the Constitution, &c. Illusted. Continued by the Rev. W. H. Pinnock, LL.D. *New edition.* 12mo 6*s.*

——— HISTORY OF GREECE. With an Introduction on the Natural and Political Geography of Greece, Dictionary of Difficult Terms, Questions for Examination, Genealogical Tables, &c. Illustrated. By Dr. W. C. Taylor. *New edition.* 12mo. 5*s.* 6*d.*

——— HISTORY OF ROME. With an Introduction, the Geography of the Roman Empire, Notices of the Roman Manners, and Illustrations, Questions for Examination, Chronological Index, &c Illustrated. By Dr. W. C. Taylor. *New edition.* 12mo. 5*s.* 6*d.*

PINNOCK'S CATECHISMS OF THE ARTS, SCIENCES, AND LITERATURE Whittaker's Improved Editions. Illustrated with Maps, Plates, and Woodcuts, carefully re-edited. 18mo. price 9*d.* each.

HISTORY.—Modern—Ancient—Universal—Bible and Gospel—Scripture—Chronology—England—Scotland—France—America—Rome—Greece—Jews.

GEOGRAPHY.—Ancient—Modern, Improved Edition—Modern, Original Edition—Sacred—England and Wales—Use of the Globes.

GRAMMAR —English—French—German—Italian—Latin—Spanish—Greek: Part I. Accidence. Part II. Syntax and Prosody—Hebrew.

MATHEMATICS, &c.—Algebra (two Parts)—Arithmetic—Geometry—Navigation—Land Surveying

RELIGION.—Religion—Natural Theology—Scripture History—Bible and Gospel History.

FINE ARTS, &c.—Architecture—Drawing—Perspective—Music—Singing.

LITERATURE.—Mythology—Rhetoric—Logic—British Biography—Classical Biography.

MISCELLANEOUS.—First Catechism—General Knowledge—Intellectual Philosophy—Agriculture—English Law—Heraldry—Medicine—Moral and Social Duties—Trade and Commerce.

SCHLEYER'S GRAMMAR, with Vocabularies of Volapuk (the Language of the World), for all Speakers of the English Language. Second (greatly Revised) Edition. By W. A. Seret, Certificated Teacher of the Universal Language. Crown 8vo. pp. 420, sewed, 5*s*. 6*d*.; cloth, 6*s*. 6*d*.

SHUMWAY (E. S.) A DAY IN ANCIENT ROME. With numerous Illustrations. By Edgar S. Shumway, Professor, Rutger's College, New Brunswick. Small 4to. cloth, 5*s*.

WATTON'S ORIGINAL AIDS TO EDUCATION.

Hand-series of Tablets, in Stiff Covers, 3*d*. each.

Leading Events of General History.
Chief Events of Old Testament History.
Chief Events of New Testament History.
Prophecies and other Scripture Subjects.
Chief Events of Grecian History.
Chief Events of Roman History.
Chief Events of Eastern Empire.
Chief Events of German History.
Chief Events of English History.
Chief English Battles and Results.
Chief Events of Scottish History.
Chief Events of French History.
Chief Events of Prussian History.
Chief Events of Russian History.
Eminent Men of Modern Times.
Chief Events of Church History.
Natural System of Botany.
The Linnæan System of Botany.
Natural History—Zoology.
Natural Philosophy.
Principles of Grammatical Analysis, with Examples.
Guide to English Parsing, with Examples.
Abstract of Heathen Mythology.
Word Formation—Saxon, Latin, and Greek Prefixes, with Examples.
Chief Grecian and Roman Battles and Results.

LARGE TYPE SERIES OF TABLETS

(20 by 23 inches), embracing Historical, Geographical, and other Subjects, 4*d*. each, for suspension.

WATTON'S SKELETON EXERCISE BOOKS.

For History, Geography, Biography, Analysis, Parsing, and Chronology, with Script Headings and Specimen Page. Price regulated by the thickness of the books, 1*s*. and 2*s*. each.
Also now ready, a filled Biographical Exercise Book, 2 Series, each 1*s*.
Charts systematically arranged with date words, 60 pages, cloth, 1*s*. Selected Descriptive Poetry, 1*s*.
Object Lessons, Nos. 1, 2, 3, and 4, 32 pp., in stiff covers, 2*d*. each.

School and University Analyses.

By the Rev. Dr. Pinnock.

AN ANALYSIS OF SCRIPTURE HISTORY; Intended for Readers of Old Testament History, and the University Examinations; with Maps, Copious Index, and Examination Questions. 18mo. cloth, 3*s.* 6*d.*

AN ANALYSIS OF NEW TESTAMENT HISTORY; Embracing the Criticism and Interpretation of the original Text; with Questions for Examination. 18mo. cloth, 4*s.*

AN ANALYSIS OF ECCLESIASTICAL HISTORY; From the Birth of Christ, to the Council of Nice, A.D. 325. With Examination Questions. 18mo. cloth, 3*s.* 6*d.*

ANALYSIS OF ENGLISH CHURCH HISTORY; comprising the Reformation period, and subsequent events; with Questions of Examination, especially intended for the Universities and Divinity Students in general. 18mo. cloth, 4*s.* 6*d.*

A SHORT ANALYSIS OF OLD TESTAMENT HISTORY. With Questions for Schools. 18mo. cloth, 1*s.* 6*d.*

A SHORT ANALYSIS OF NEW TESTAMENT HISTORY. With Questions for Schools. 18mo. cloth, 1*s.* 6*d.*

Arithmetic and Euclid.

PINNOCK'S ARITHMETICAL TABLES OF MONEY, WEIGHTS, AND MEASURES. With Questions for Examination, and Explanatory Notes, &c. 18mo. 3*d.*

——— FIRST CIPHERING BOOK. Containing Easy Exercises in the First Rules of Arithmetic. 4to. sewed, 1*s.*

RYAN'S CIVIL SERVICE ARITHMETICAL EXAMINATION PAPERS. By L. J. Ryan. Cloth, 2*s.*

——— Key to Ditto. 1*s.* 6*d.*

SONNENSCHEIN AND NESBITT'S ARITHMETIC. The Science and Art of Arithmetic for the use of Schools. Post 8vo. 5*s*. 6*d*. Or separately, Part I.—Integral. 2*s*. 6*d*. Parts II. and III.—Fractional and Approximate Calculations. 3*s*. 6*d*. Answers to the Exercises. 1*s*. 6*d*. Exercises separately. Part I. 1*s*. Parts II. and III. 1*s*. 3*d*.

——— A B C OF ARITHMETIC. Teacher's Book, Nos. 1 and 2, each 1*s*. Exercise Book, Nos. 1 and 2, each 4*d*.

WALKINGAME'S TUTOR ASSISTANT (FRASER'S). Being a Compendium of Arithmetic and a Complete Question Book. 12mo. 2*s*. Key, 3*s*.

EUCLID, THE FIRST BOOK OF. With an Introduction and Collection of Problems for the use of Schools. By J. M. Wilson, M.A. *2nd edition*. 4to. 2*s*.

EUCLID, THE FIRST SIX BOOKS, together with the ELEVENTH and TWELFTH. From the Text of Dr. Simson. *New edition*, revised and corrected by S. Maynard. 18mo. 4*s*.

MODERN LANGUAGES.

French.

BARRÈRE (A.) PROFESSOR, R.M.A. Woolwich.

——— RÉCITS MILITAIRES. Selections from modern French authors, with short biographical introductions in French, and English notes for the use of army students and others. Crown 8vo. 3*s*.

——— PRÉCIS OF COMPARATIVE FRENCH GRAMMAR AND IDIOMS, and Guide to Examinations. Cloth. *Second edition, revised*, 3*s*. 6*d*.

——— JUNIOR GRADUATED FRENCH COURSE affording materials for Translation, Grammar, and Conversation. Being an introduction to the Graduated French Course. Cloth, 1*s*. 6*d*.

——— ELEMENTS OF FRENCH GRAMMAR AND FIRST STEPS IN IDIOMS. With numerous Exercises and a Vocabulary, being an Introduction to the Précis of Comparative French Grammar. Crown 8vo. cloth, 2*s*.

BELLENGER'S MODERN FRENCH CONVERSATION. Containing Elementary Phrases and New Easy Dialogues, in French and English, on the most familiar subjects. 12mo. *2s. 6d.*

BOSSUT'S FRENCH WORD BOOK. 18mo. *1s.*

——— FRENCH PHRASE BOOK. 18mo. *1s.*

BOWER. PUBLIC EXAMINATION FRENCH READER. With a Vocabulary to every extract, suitable for all Students who are preparing for a French Examination. By A. M. Bower, F.R.G.S., late Master in University College School, &c. Cloth, *3s. 6d.*

"The book is a very practical and useful one, and it must prove very handy for students who are preparing for a French examination, the persons for whose special aid it has been specially provided. It would also serve admirably for use in schools as a class book."—*Schoolmaster.*

DELILLE'S FRENCH GRAMMAR. In Two Parts. I.—Accidence. II.—Syntax, written in French, with Exercises conducive to the speaking of the French Language, &c. 12mo. *5s. 6d.* Key, *3s.*

——— EASY FRENCH POETRY FOR BEGINNERS; or, Short Selections in Verse on a Graduated Plan for the Memory. With English Notes. 12mo. *2s.*

DELILLE'S MODÈLES DE POÉSIE FRANÇAIS. With Treatise on French Versification. *New edition.* 12mo. *6s.*

——— RÉPERTOIRE DES PROSATEURS FRANCAIS. With Biographical Sketches, &c. *New edition.* 12mo. *6s. 6d.*

——— MANUEL ÉTYMOLOGIQUE; or, an Interpretative Index of the most recurrent Words in the French Language. 12mo. *2s. 6d.*

——— BEGINNER'S OWN FRENCH BOOK. Being a Practical and Easy Method of Learning the Elements of the French Language. 12mo. cloth, *2s.* Key, *2s.*

DES CARRIÈRES' FRENCH IDIOMATICAL PHRASES AND FAMILIAR DIALOGUES. Square, *3s. 6d.*

DES CARRIÈRES' HISTOIRE DE FRANCE, DEPUIS L'ETABLISSEMENT DE LA MONARCHIE. Continuée jusqu'au rétablissement de l'Empire sous Napoleon III., par C. J. Delille. 12mo. 7*s.*

DUVERGER'S COMPARISON BETWEEN THE IDIOMS, GENIUS, AND PHRASEOLOGY OF THE FRENCH AND ENGLISH LANGUAGES. *New edition.* 12mo. 4*s.* 6*d.*

GASC (F. E. A.) AN IMPROVED MODERN POCKET DICTIONARY OF THE FRENCH AND ENGLISH LANGUAGES. *New edition.* 16mo. cloth, 2*s.* 6*d.* Also in 2 vols. in neat leatherette, 5*s.*

——— MODERN FRENCH-ENGLISH AND ENGLISH-FRENCH DICTIONARY. *New edition, revised.* In 1 vol. 8vo. 10*s.* 6*d.*

HAMEL'S NEW UNIVERSAL FRENCH GRAMMAR. *New Edition.* 12mo. 4*s.*

——— GRAMMATICAL EXERCISES UPON THE FRENCH LANGUAGE. *New edition.* 12mo. 4*s.* Key, 3*s.*

——— FRENCH GRAMMAR AND EXERCISES. *New edition.* 12mo. 5*s.* 6*d.* Key, 4*s.*

LEVIZAC'S DICTIONARY OF THE FRENCH AND ENGLISH LANGUAGES. *New edition*, by N. Lambert. 12mo. 6*s.* 6*d.*

NUGENT'S POCKET DICTIONARY OF THE FRENCH AND ENGLISH LANGUAGES. *New edition*, revised by J. C. J. Tarver. *Pearl edition*, 4*s.* 6*d.*

OLLENDORFS (Dr. H. G.) NEW METHOD OF LEARNING TO READ, WRITE, AND SPEAK A LANGUAGE IN SIX MONTHS. Adapted to the French. *New edition.* 12mo. 6*s.* 6*d.* Key, 8vo. 7*s.*

PRACTICAL COMMERCIAL CORRESPONDENCE. *See Miscellaneous.*

Whittaker's French Series.

For the use of Schools and Private Students. Edited by A. Barrère, Prof. R.M.A. Woolwich, &c., and others. Each number with a literary Introduction and Arguments in English, foot-notes explaining the more difficult passages, and translations of the idiomatic expressions into the corresponding English idioms.

Fcap. 8vo, each number, sewed, 6*d.*; cloth, 9*d.*

Now Ready:—

1. SCRIBE. LE VERRE D'EAU. Barrère.
2. MOLIERE. LE BOURGEOIS GENTILHOMME. Gasc.
3. MOLIERE. L'AVARE. Gasc.
4. SOUVESTRE. SOUS LA TONNELLE. Desages.
5. MOLIERE. LE MISANTHROPE. Gasc.
6. GALLAND. ALI BABA. Clare.
7. CORNEILLE. LE CID. Gasc.

8, 9. LAMARTINE. JEANNE D'ARC. Barrère.

10, 11. PIRON. LA METROMANIE. Delbos.

Others to follow.

Whittaker's French Classics, with English Notes.

Fcap. 8vo. cloth.

AVENTURES DE TELEMAQUE. Par Fénélon. *New edition.* Edited and revised by C J. Delille. 2*s.* 6*d.*

HISTOIRE DE CHARLES XII. Par Voltaire. *New edition.* Edited and revised by L. Direy. 1*s.* 6*d.*

PICCIOLA. Par X. B. Saintine. *New edition.* Edited and revised by Dr. Dubuc. 1*s.* 6*d.*

SELECT FABLES OF LA FONTAINE. *New edition.* Edited by F. Gasc, M.A. 1*s.* 6*d.*

Whittaker's Series of Modern French Authors.

WITH INTRODUCTION AND NOTES.

For Beginners.

LA BELLE NIVERNAISE. Histoire d'un vieux bateau et de son équipage. By Alphonse Daudet. With 6 illustrations. Edited by James Boïelle, Senior French Master at Dulwich College. 2*s.* 6*d.* [*Ready.*

For Advanced Students.

BUG JARGAL. By Victor Hugo. Edited by James Boïelle, Senior French Master at Dulwich College. 3*s.* *Others to follow.* [*Ready.*

German.

FLÜGEL'S COMPLETE DICTIONARY OF THE GERMAN AND ENGLISH LANGUAGES. Comprising the German and English, and English and German. Adapted to the English Student, with great Additions and Improvements. By C. A. Feiling, A. Heimann, and J. Oxenford. *New edition.* 2 vols. 8vo. 1*l.* 1*s.*

—— ABRIDGED GERMAN AND ENGLISH, AND ENGLISH AND GERMAN DICTIONARY. Carefully compiled from the larger Dictionary. By C. A. Feiling and J. Oxenford. *New edition.* Royal 18mo. 6*s.*

GRENFELL'S ELEMENTARY GERMAN EXERCISES. Part I. Adapted to the Rugby School German Accidence. 12mo. 1*s.* 6*d.*

OLLENDORFF'S (Dr. H. S.). NEW METHOD OF LEARNING TO READ, WRITE, AND SPEAK A LANGUAGE IN SIX MONTHS. Adapted to the German. *New edition.* Crown 8vo. 7*s.* Key, 8vo. 7*s.*

SHELDON (E.S.) A SHORT GERMAN GRAMMAR FOR HIGH SCHOOLS AND COLLEGES. Crown 8vo. 3*s*.

WHITTAKER'S COURSE OF MODERN GERMAN. By F. Lange, Ph.D., Professor, R.M.A. Woolwich, Examiner in German to the College of Preceptors, London; Examiner in German at the Victoria University, Manchester, and J. F. Davis, M.A., D.Lit. Extra fcap. 8vo. cloth.

A CONCISE GERMAN GRAMMAR. With especial reference to Phonology, Comparative Philology, English and German Correspondences, and Idioms. By Frz. Lange, Ph.D., Professor at the Royal Military Academy, Woolwich. In three Parts. Part I., Elementary, 2*s*. Part II., Intermediate, 2*s*. Part III. complete.

ELEMENTARY GERMAN READER. A Graduated Collection of Readings in Prose and Poetry. With English Notes and a Vocabulary. By F. Lange, Ph.D. 1*s*. 6*d*.

ADVANCED GERMAN READER. A Graduated Collection of Readings in Prose and Poetry. With English Notes and a Vocabulary. By F. Lange, Ph.D. and J. F. Davis, M.A., D.Lit. [*Nearly ready.*

PROGRESSIVE GERMAN EXAMINATION COURSE. In Three Parts. By F. Lange, Ph.D., Prof. R.M.A., Woolwich, Examiner in German to the College of Preceptors.

Comprising the Elements of German Grammar, an Historical Sketch of the Teutonic Languages, English and German Correspondences, Materials for Translation, Dictation, Extempore, Conversation and complete Vocabularies.

1. ELEMENTARY COURSE. Cloth, 2*s*.
2. INTERMEDIATE COURSE. Cloth, 2*s*.
3. ADVANCED COURSE. Second revised edition. Cloth, 1*s*. 6*d*.

"We cordially commend it as a useful help to examiners, who will find it well adapted to their needs."—*Practical Teacher.*

German Classics, with English Notes.

Fcap. 8vo. cloth.

GERMAN BALLADS. From Uhland, Goethe, and Schiller. With Introductions to each Poem, copious Explanatory Notes, and Biographical Notices. By C. Bielefeld. 1*s*. 6*d*.

GOETHE'S HERMANN AND DOROTHEA. With Short Introduction, Argument, and Notes Critical and Explanatory. By Ernest Bell and E. Wölfel. 1*s*. 6*d*.

SCHILLER'S MAID OF ORLEANS. With Introduction and Notes. By Dr. Wagner. 1*s*. 6*d*.

——— MARIA STUART. With Introduction and Notes. By V. Kastner, M.A. 1*s*. 6*d*.

——— WALLENSTEIN. Complete Text. *New edition*. With Notes, Arguments, and an Historical and Critical Introduction. By C. A. Buchheim, Professor, Ph.D., 5*s*. Or separately—Part I.—THE LAGER AND DIE PICCOLOMINI. 2*s*. 6*d*. Part II.—WALLENSTEIN'S TOD. 2*s*. 6*d*.

Whittaker's Series of Modern German Authors.

With Introduction and Notes. Edited by F. Lange, Ph.D., Professor, Royal Military Academy, Woolwich.

The attention of the heads of Colleges and Schools is respectfully directed to this new Series of "MODERN GERMAN AUTHORS" which is intended to supply the much-felt want of suitable Reading Books for English Students of German who have passed through the preliminary stages of fables and anecdotes.

To those who wish to extend their linguistic and grammatical

knowledge, these volumes will afford, in one respect, a great advantage over those of an earlier period, presenting, as they do, the compositions of the best living, or only recently deceased authors. The Notes, besides etymological and other explanations, will contain many useful idiomatic expressions suggested by the text, and worth committing to memory.

FIRST SERIES.

FOR BEGINNERS. Edited, with a Grammatical Introduction, Notes, and a Vocabulary, by F. Lange, Ph.D., Professor, R.M.A. Woolwich, Examiner in German to the College of Preceptors, and H. Hager, Ph.D., Examiner in German to the London University.

HEY'S FABELN FÜR KINDER. Illustrated by O. Speckter. Edited, with an Introduction, Grammatical Summary, Words, and a complete Vocabulary. By F. Lange, Ph.D., Professor. 1*s.* 6*d.*

THE SAME, with a Phonetic Introduction, Phonetic Transcription of the Text. By F. Lange, Professor, Ph.D. 2*s.*

SECOND SERIES.

FOR INTERMEDIATE STUDENTS. Edited, with a Biographical Introduction, Notes, and a complete vocabulary, by F. Lange, Ph.D., Professor, and H. Hager, Ph.D.

DOKTOR WESPE. Lustspiel in fünf Aufzügen von JULIUS RODERICH BENEDIX. Edited by F. Lange, Ph.D., Professor. 2*s.* 6*d.*

SCHILLER'S JUGENDJAHRE. Erzählung von FRZ. HOFFMANN. Edited by H. Hager, Ph.D., Professor. [*In the press.*

THIRD SERIES.

FOR ADVANCED STUDENTS. Edited, with a Literary Introduction and Notes, by F. Lange, Ph.D., Professor, R.M.A. Woolwich, in co-operation with F. Storr, B.A.; A. A. Macdonell, M.A.; H. Hager, Ph.D.; C. Neuhaus, Ph.D. and others.

MEISTER MARTIN, der Küfner. Erzählung von E. T. A. Hoffman. Edited by F. Lange, Ph.D., Professor, Royal Military Academy, Woolwich. 1*s.* 6*d.*

HANS LANGE. Schauspiel von Paul Heyse. Edited by A. A. Macdonell, M.A., Ph.D., Taylorian Teacher, University, Oxford. 2*s.*

AUF WACHE. Novelle von Berthold Auerbach. DER GEFRORENE KUSS. Novelle von Otto Roquette. Edited by A. A. Macdonell, M.A. 2*s.*

DER BIBLIOTHEKAR. Lustspiel von G. von Moser. Edited by F. Lange, Ph.D. Second revised Edition. 2*s.*

EINE FRAGE. Idyll von George Ebers. Edited by F. Storr, B.A., Chief Master of Modern Subjects in Merchant Taylor's School. 2*s.*

DIE JOURNALISTEN. Lustspiel von Gustav Freytag. Edited by Professor F. Lange, Ph.D. Second revised Edition. 2*s.* 6*d.*

ZOPF UND SCHWERT. Lustspiel von Karl Gutzkow. Edited by Professor F. Lange, Ph.D. 2*s.* 6*d.*

GERMAN EPIC TALES IN PROSE. I. Die Nibelungen, von A. F. C. Vilmar.—II. Walther und Hildegund, von Albert Richter. Edited by Karl Neuhaus, Ph.D., the International College, Isleworth. 2*s.* 6*d.*

Italian.

BARETTI'S DICTIONARY OF THE ENGLISH AND ITALIAN LANGUAGES. To which is prefixed an Italian and English Grammar. *New Edition,* entirely re-written. By G. Comelati and J. Davenport. 2 vols. 8vo. 1*l.* 1*s.*

GRAGLIA'S NEW POCKET DICTIONARY OF THE ITALIAN AND ENGLISH LANGUAGES. With considerable Additions, and a Compendious Elementary Italian Grammar. 18mo. 4*s.* 6*d.*

OLLENDORFF'S (DR. H. G.) NEW METHOD OF LEARNING TO READ, WRITE, AND SPEAK A LANGUAGE IN SIX MONTHS. Adapted to the Italian. *New Edition.* Crown 8vo. 7*s.* Key, 8vo. 7*s.*

SOAVE'S NOVELLE MORALI. *New Edition.* 12mo. 4*s.*

VENERONI'S COMPLETE ITALIAN GRAMMAR. By P. Rosteri. 12mo. 6*s*.

VERGANI AND PIRANESI'S ITALIAN AND ENGLISH GRAMMAR. With Exercises, &c. By J. Guichet. *New edition*, by Signor A. Tommasi. 12mo. 5*s*. Key, 3*s*.

Russian.

DOLBESHOFF (E.) A DICTIONARY OF THE RUSSIAN AND ENGLISH LANGUAGES. In two volumes. Vol. I. Russian-English. Vol. II. English-Russian. Compiled by E. Dolbeshoff in co-operation with C. E. Turner, Professor of English Language and Literature at the University, St. Petersburg. [*Preparing*.

Spanish.

NEUMAN AND BARETTI'S SPANISH AND ENGLISH, AND ENGLISH AND SPANISH DICTIONARY. Revised and enlarged by M. Seoane, M.D. 2 vols. 8vo. 1*l*. 8*s*.

—— POCKET DICTIONARY. Spanish and English, and English and Spanish. Compiled from the larger work. 18mo. 5*s*.

OLLENDORFF'S (**DR. H. G.**) NEW METHOD OF LEARNING TO READ, WRITE, AND SPEAK A LANGUAGE IN SIX MONTHS. Adapted to the Spanish. *New edition.* 8vo. 12*s*. Key, 8vo. 7*s*.

PONCE DE LEON'S ENGLISH - SPANISH TECHNOLOGICAL DICTIONARY. 8vo. 1*l*. 16*s*. *See page* 31.

Practical Mercantile Correspondence.

A Collection of Commercial Letters and Forms, with Notes, Explanatory and Grammatical, and a Vocabulary of Commercial Terms, edited by L. Simon, Chr. Vogel, Ph.D., H. P. Skelton, W. C. Wrankmore, Leland Mason, and others. Intended as Class Books for Schools and for Self-Instruction.

Now Ready, crown 8vo, cloth:

ENGLISH, with German Notes, 3*s.*
GERMAN, with English Notes, 3*s.*
ENGLISH, with French Notes, 4*s.* 6*d.*
FRENCH, with English Notes, 4*s.* 6*d.*

This new Collection of Model Letters and Epistolary Forms embraces the whole sphere of Commercial Transactions. Each example is provided with such remarks and explanations, that any one with a fair grammatical knowledge of the particular language will find it an easy matter to prepare a well-expressed letter.

The Specialist's Series.

A New Series of Handbooks for Students and Practical Engineers. Crown 8vo. With many Illustrations.

GAS ENGINES. Their Theory and Management. By William Macgregor. With 7 Plates. Crown 8vo. pp. 245, 8*s.* 6*d.*

BALLOONING: A Concise Sketch of its History and Principles. From the best sources, Continental and English. By G. May. With Illustrations. Crown 8vo. pp. vi.-97, 2*s.* 6*d.*

ELECTRIC TRANSMISSION OF ENERGY, and its Transformation, Subdivision, and Distribution. A Practical Handbook by Gisbert Kapp, C.E., Associate Member of the Institution of Civil Engineers, &c. With 119 Illustrations. Crown 8vo. pp. xi.-331. *Second Edition.* 7*s.* 6*d.*

ARC AND GLOW LAMPS. A Practical Handbook on Electric Lighting. By Julius Maier, Ph.D., Assoc. Soc. Tel. Eng., &c. With 78 Illustrations. Crown 8vo. pp. viii.-376. 7*s.* 6*d.*

ON THE CONVERSION OF HEAT INTO WORK. A Practical Handbook on Heat-Engines. By William Anderson, M. Inst. C.E. With 64 Illustrations. Pp. viii.-254. *Second Edition.* Cr. 8vo. 6*s*.

SEWAGE TREATMENT, PURIFICATION AND UTILIZATION; A Practical Manual for the Use of Corporations, Local Boards, Officers of Health, Inspectors of Nuisances, Chemists, Manufacturers, Riparian Owners, Engineers and Ratepayers. By J. W. Slater, F.E.S., Editor of "Journal of Science." Crown 8vo. cloth, price 6*s*.

THE TELEPHONE. By W. H. Preece, F.R.S., and J. Maier, Ph.D. With numerous illustrations. Cr. 8vo. 12*s*. 6*d*.

MANURES, OR THE PHILOSOPHY OF MANURING. By Dr. A. B. Griffiths, F.R.S.Ed., F.C.S., Principal and Lecturer on Chemistry in the School of Science, Lincoln, &c., &c. Cr. 8vo. 7*s*. 6*d*.

HYDRAULIC MOTORS: TURBINES AND PRESSURE MOTORS. By George R. Bodmer, Assoc. M.Inst.C.E. 14*s*.

ALTERNATING CURRENTS OF ELECTRICITY. By Thomas H. Blakesley, M.A., M.Inst.C.E. 4*s*. 6*d*.

In preparation.

GALVANIC BATTERIES. By Professor George Forbes, M.A.

INDUCTION COILS. By Professor A. J. Fleming, M.A., D.Sc.

THE DYNAMO. By Guy C. Fricker.

Others to follow.

NIPHER (F. E.) THEORY OF MAGNETIC MEASUREMENTS, WITH AN APPENDIX ON THE METHOD OF LEAST SQUARES. One volume. Crown 8vo. cloth, 5*s*.

PLANTÉ (G.) THE STORAGE OF ELECTRICAL ENERGY, and Researches in the Effects created by Currents combining Quantity with High Tension. Translated from the French by Paul Bedford Elwell. With Portrait, and 89 Illustrations. 8vo. pp. vii.-268, cloth, 12*s*.

Small crown 8vo. cloth. With many Illustrations.

Whittaker's Library of Arts, Sciences, Manufactures and Industries.

ELECTRIC LIGHT INSTALLATIONS AND THE MANAGEMENT OF ACCUMULATORS. A Practical Handbook by Sir David Salomons, Bart., M.A. 5th Edition, Revised and Enlarged, with 100 Illustrations. Cloth, 5*s*.

"To say that this book is the best of its kind would be a poor compliment, as it is practically the only work on accumulators that has been written."—*Electrical Review.*

ELECTRICAL INSTRUMENT-MAKING FOR AMATEURS. A Practical Handbook. By S. R. Bottone, Author of "The Dynamo," &c. With 60 Illustrations. Third edition. Cloth, 3*s*.

ELECTRIC BELLS AND ALL ABOUT THEM. A Practical Book for Practical Men. By S. R. Bottone. With more than 100 illustrations. *Second edition, revised.* Cloth, 3*s*.

PRACTICAL IRON FOUNDING. By the Author of "Pattern Making," &c., &c. Illustrated with over one hundred engravings. Cloth, 4*s*.

ELECTRICAL ENGINEERING IN OUR HOMES AND WORKSHOPS. A Practical Handbook. By Sydney F. Walker, M.Inst.C.E., M.I.E.E. 5*s*.

THE PROTECTION OF BUILDINGS FROM LIGHTNING. A Treatise on the Theory of Lightning Conductors from a Modern Point of View. Being the substance of two lectures delivered before the Society of Arts in March, 1888. By Oliver J. Lodge, LL.D., D.Sc., F.R.S., Professor of Physics in University College, Liverpool.

Published with various amplifications and additions, with the approval of the Society of Arts. [*In preparation.*

ELECTRICAL INFLUENCE MACHINES: Containing a full account of their historical development, their modern Forms, and their Practical Construction. By J. Gray. B.Sc. [*In the press.*

METAL TURNING. By J. A., author of "Practical Ironfounding," &c. [*In the press.*

Others in preparation.

Technological Dictionaries.

ENGLISH AND GERMAN.

WERSHOVEN (F. J.) TECHNOLOGICAL DICTIONARY OF THE PHYSICAL, MECHANICAL, AND CHEMICAL SCIENCES. English and German. 2 vols. cloth, 5*s.*

ENGLISH—SPANISH.

PONCE DE LEON. TECHNOLOGICAL DICTIONARY. English-Spanish and Spanish-English. Containing Terms employed in the Applied Sciences, Industrial Arts, Mechanics, Fine Arts, Metallurgy, Machinery, Commerce, Ship-building and Navigation, Civil and Military Engineering, Agriculture, Railway Construction, Electro-technics, &c.

Vol. I.—English-Spanish. 8vo. bound, £1 16*s.*

Vol. II.—Spanish-English. [*In preparation.*

Post 8*vo.* 814 *pp.* 10*s.* 6*d.*

HOBLYN'S DICTIONARY OF TERMS USED IN MEDICINE AND COLLATERAL SCIENCES. 11*th edition.* Revised throughout, with numerous Additions. By John A. P. Price, B.A., M.D. Oxon., Assistant-Surgeon to the Royal Berkshire Hospital.

This new edition has undergone complete revision and emendation. Many terms, fallen more or less into disuse, have been omitted; and a considerable amount of fresh matter has been introduced, in order to meet the requirements of the present day.

CHISWICK PRESS:—C. WHITTINGHAM AND CO., TOOKS COURT, CHANCERY LANE.